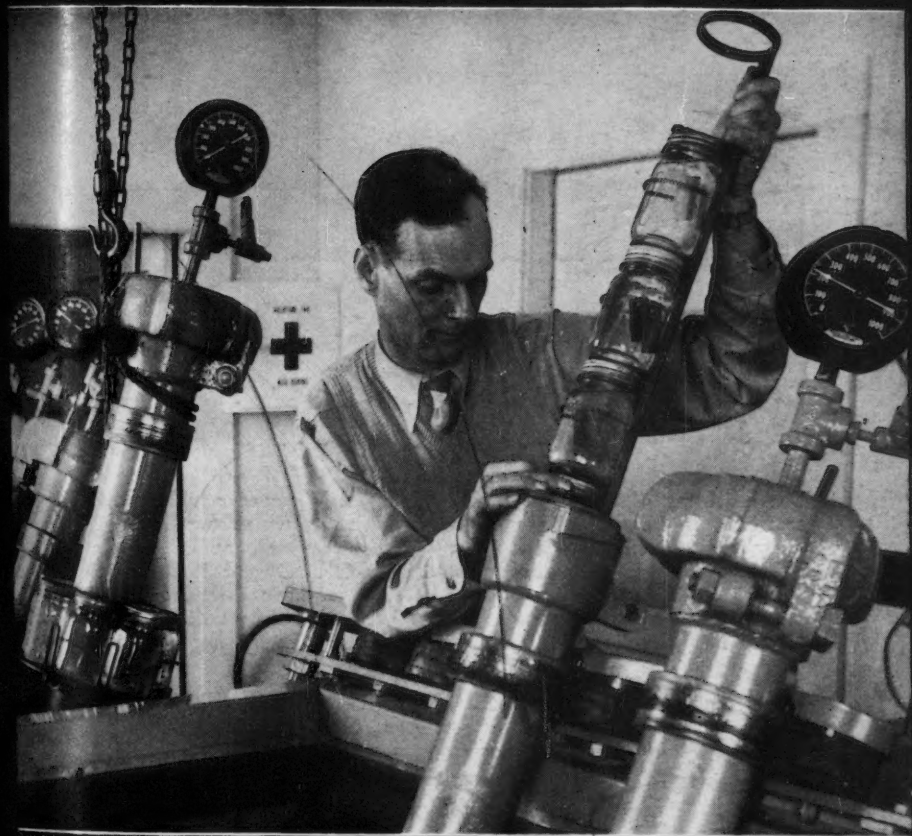


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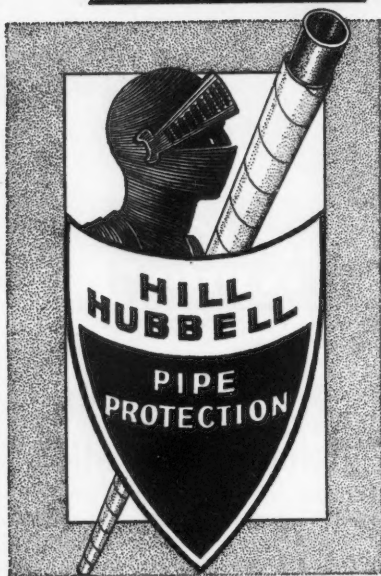


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devoted entirely to

CORROSION

Research and Control

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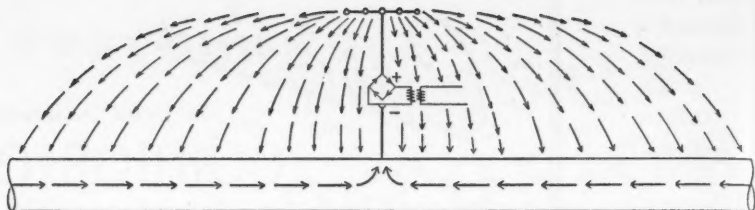


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THIS MONTH'S COVER

• Removing jars containing metal coupons from pressure-cell and constant temperature bath used in determining rates of corrosion of steels and alloys in liquid mediums having the characteristics of fluids found in certain gas-condensate wells. (See page 245). Photograph courtesy Bureau of Mines, Bartlesville, Okla.



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A Message from Your Officers

This Month's Contributor

PAUL W. BACHMAN, Director
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AS PERHAPS the most recent of your Directors, it is with some hesitancy that I write this. Since I have not had the benefit of previous contacts with your officers, I can only express myself as an individual, and by so doing risk finding my thoughts at variance with those of other members of your directorate. This is both an advantage and a disadvantage. An advantage in that only by being subjected to the impact of differing thoughts can we progress as a well-rounded national association; and a disadvantage in that I may find myself guilty of not fully appreciating that which is in progress. But if the latter is the case, no harm will be done by the repetition.

I believe that the existence of any group is justified only by the useful part which they play in life. If this criterion is applied to our Association, I think there is little doubt that our existence is justified. But while we state that we are an association concerned with the control of corrosion, I am of the opinion that our real interests extend far beyond that statement. Control of corrosion implies that we take existing knowledge and apply it to practical methods for preventing or controlling corrosion. We might then, by definition, consider ourselves as a group concerned with applying existing fundamental scientific knowledge to practical purposes. To me, this is but one of our objectives; the other is concerned with the acquisition of fundamental knowledge.

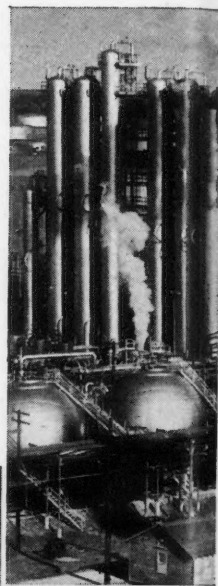
As a society, I believe that we should encourage fundamental scientific investigations into the mechanism, nature, and causes of corrosion. Such studies, probably best conducted in the academic environment of our universities, would serve to further advance the frontier of knowledge. The questions requiring answers are numerous. It seems to me that for our Association to grow and command the respect which we desire, we must encourage work in both the theoretical and practical aspects of corrosion.

Initially we emphasized the practical aspects to a marked degree. Now, with-out decreasing the emphasis upon the practical side, we are beginning to encourage theoretical investigations. This is evidenced by our Willis Rodney Whitney Award giving recognition to the fundamental scientist. It is only by continuing to encourage research in the theoretical as well as the practical aspects of corrosion that we can reach our objective of becoming an outstanding national organization.



*The Honorable
Mr. Robert Boyle, F.R.S.*

**"I am very shy of using
corrosive liquors"**



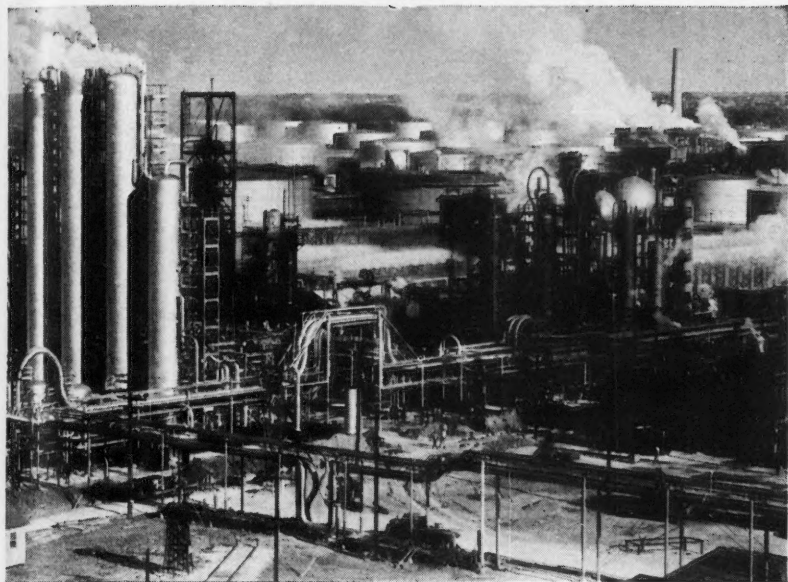
THE Honorable Mr. Robert Boyle, F.R.S. was very shy of using corrosive liquors, as he said, because they ruined his costly experimental vessels.

The tender heart of *"The Sceptical Chemist"* also made him shy of anatomical studies.

Robert Boyle was one of the founders of the Royal Society, but he refused to accept the Presidency because he was shy about taking an oath. And although he was too shy to marry, he devoted his life to science and is believed by many to be "The Father of Modern Chemistry."

Doubtless this distinguished pioneer, who published his first book on chemistry in the year 1661, would not be so shy today. The modern chemical industry, which Boyle did so much to initiate, has indispensable need of corrosive materials and handles them safely and efficiently all the time. If the corrosive "liquors" of three centuries ago were difficult to handle, what shall we say about some of the fiercer present-day commercial products, such as liquid fluorine and not-quite anhydrous caustic? They can be safely managed, but it is still necessary to make a proper selection of equipment materials, and without experienced advice that selection is not always easy to make.

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In most cases it is unsafe to generalize about the "best" metal for a given use without specific data on that use; and even when one has such data it is often dangerous to extrapolate the figures to any considerable extent, and always necessary to interpret them properly. It is no secret that a dilute solution of a corrosive is often more aggressive than a concentrated one, that a violently agitated solution may be less damaging than a stagnant one, and that a cold solution sometimes makes more trouble than a hot one which expels volatile corrosive constituents. Such apparent paradoxes can be multiplied indefinitely, and they serve to make us all shy of unwarranted generalizations.

In the files of INCO's Corrosion Engineering Section are the tabulated results of thousands of corrosion tests undertaken to meet the needs of specific metal applications. Not forgetting for a moment the important need for proper interpretation of such tests, we make this information available with appropriate comment to all persons who have a technical interest in the solution of a specific corrosion problem. If you have such a problem we will be glad to send you a copy of our Corrosion Data Work Sheet, which simplifies for all concerned the orderly and uniform presentation of the essential factors. No obligation is involved.

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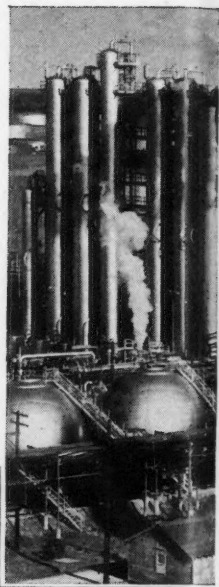


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Mr. Robert Boyle, F.R.S.*

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corrosive liquors"**



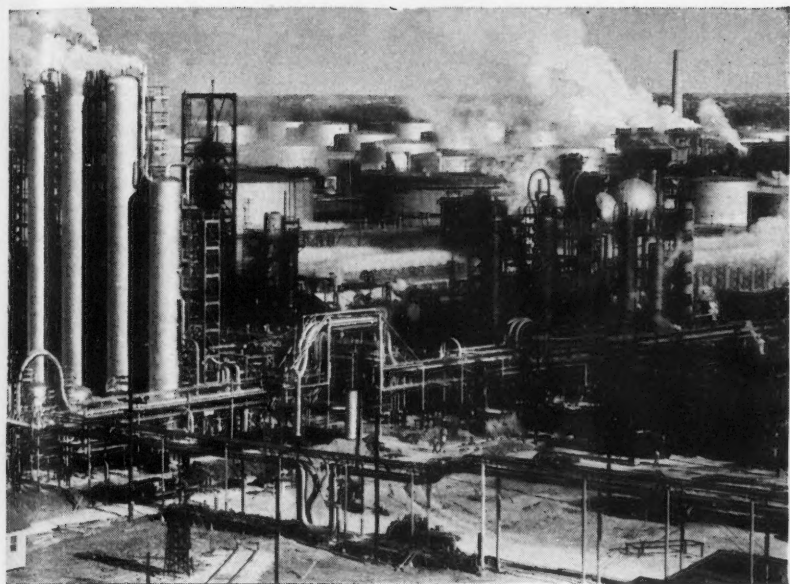
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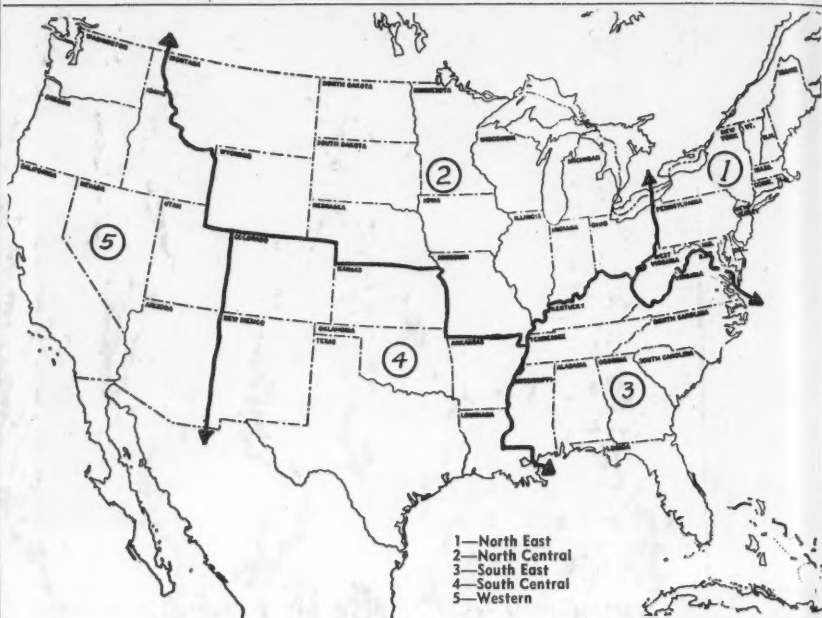
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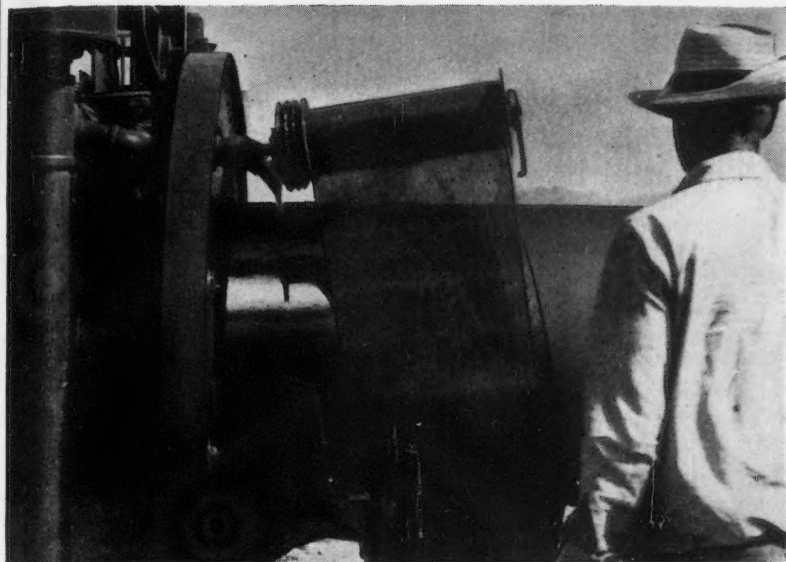
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is a non-profit, scientific and research association of individuals and companies concerned with corrosion or interested in it, whose objects are:

(a) to promote scientific research in determining the causes of corrosion and methods of its control with respect to theory and practice.

(b) to provide a means of exchange of knowledge and ideas among those individuals actively engaged in the control of corrosion.

(c) to promote methods of control of corrosion.

(d) to promote standardization of terminology, methods, equipment and design in the development of methods of corrosion control.

(e) to foster cooperation between individual owners of metallic structures in the solution of their joint corrosion problems.

It is an incorporated association without capital stock, chartered under the laws of Texas. Its affairs are governed by a Board of Directors, elected by the general membership. Officers are nominated by (1) the Board of Directors, or (2) a quorum of at least 25 members, and elected by the membership.

Inquiries regarding membership, and all general correspondence should be directed to the Executive Secretary at the administrative headquarters of the National Association of Corrosion Engineers at 905 Southern Standard Building, 711 Main Street, Houston 2, Texas.



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Alloying Steels for Corrosion Resistance to Gas-Condensate Fluids* -Part 1

By K. K. Eilerts,¹ Faye Green,² F. G. Archer,³

Betty Hanna⁴ and L. M. Burman⁵

Resume

THE BUREAU OF MINES has made laboratory tests of the relative merits of various steels and alloys for resisting the corrosion that occurs in high-pressure gas-condensate wells. The results of the tests indicate that a steel containing approximately 9 percent chromium would provide the best combination of corrosion resistance, physical strength, and cost economy of any of the steels tested. A steel containing 7 percent chromium would sustain less weight loss than the carbon steel now manufactured to meet API grade J-55 specifications for tubing and would not be subject to serious pitting corrosion. Laboratory tests indicate that a steel containing 9-percent nickel would not be subject to the severe pitting corrosion that is characteristic of the carbon steel tubing now used in wells and would

be subject to lower rates of weight loss. Tests, made in the field, exposing coupons of metals in the flowstream of wells have indicated that 9-percent nickel steel has relatively high resistance to corrosion by gas-condensate fluids.

The chromium-nickel stainless steels and copper-nickel alloys exhibit high resistance to corrosion. These metals could be used in the manufacture of special fittings provided the nature and distribution of the phases in the flowstream permit the use of dissimilar metals in contact with one another.

Introduction

Control of corrosion in gas-condensate wells is an engineering problem involving high costs. Since Bacon and Brown¹ observed and first described this type of corrosion in 1943, damage to high-pressure well equipment has been experienced in many fields. Regarding a survey completed in March, 1946; of 62 gas-condensate fields, West² wrote:

"From the data presented it appears safe to say that in excess of two-thirds of all the present producing distillate fields are corrosive.

* A paper presented at the Annual Meeting of NACE in Chicago, Ill., April 7-10, 1947.

1. Senior physical chemist; Bureau of Mines, Bartlesville, Okla.

2. Scientific aide, Bureau of Mines, Bartlesville, Okla.

3. Laboratory mechanic, Bureau of Mines, Bartlesville, Okla.

4. Formerly junior physicist, Bureau of Mines, Bartlesville, Okla.

5. Assistant chemical engineer, Bureau of Mines, Bartlesville, Okla.

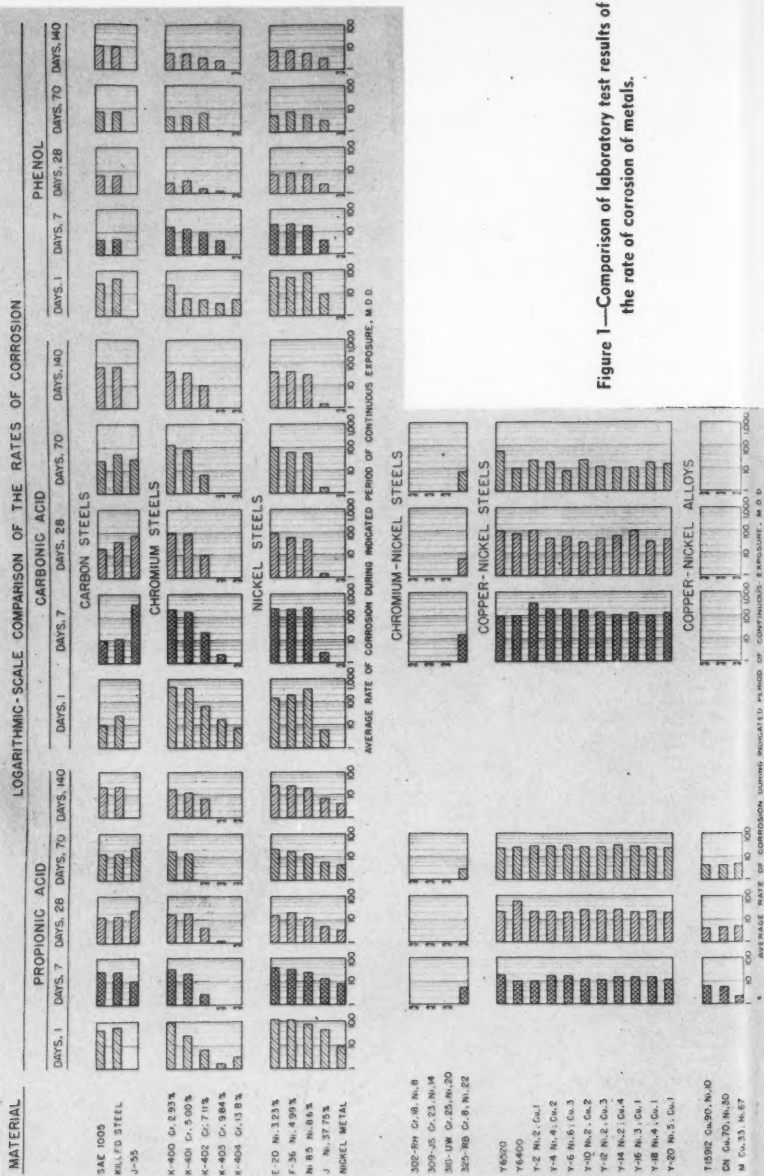


Figure 1—Comparison of laboratory test results of the rate of corrosion of metals.

About one-third of the corrosive fields are seriously corrosive, and about two-thirds are moderately or only slightly corrosive. Fields considered seriously corrosive are those in which tubing strings, tree fittings, or flow lines receive sufficient corrosive action to necessitate their renewal in the order of once a year."

The nature and extent of the corrosion that occurs in gas-condensate wells vary from field to field, and numerous methods for combating it are practiced. Replacement of tubing, wellhead fittings and flowlines, continuous or intermittent injection of treating agents into high-pressure wells, periodic inspection of equipment and checking of the efficiency of the control methods, and reduction of rates of flow from wells all contribute to the high cost of corrosion. For a number of important fields for which estimates have been made³ corrosion adds \$4 to \$5 to the cost of producing a million cubic feet of gas.

Lines of Approach

To aid in the development of means of minimizing corrosion of high-pressure equipment in gas-condensate fields the Bureau of Mines has followed two principal lines of approach. They are: (1) Testing inhibitors and treating agents^{4,5} and developing methods of treating the fluid in the flow stream⁶ to reduce the corrosion of carbon-steel well equipment; and (2) testing of alloy steels for resistance to the corrosive action of gas-condensate fluids. This report presents the results obtained in testing commercially available metals and special alloy steels to determine those that have the properties required for service in high-

pressure, gas-condensate wells subject to corrosion. The metals were selected and the tests were conducted to provide information for modifying standard metals, if necessary, to obtain materials better suited for the special service.

Summary of Test Results

Aqueous solutions of carbonic acid, propionic acid, and phenol, maintained at 130° F., were the mediums used in determining the relative resistance to corrosion of 72 alloys and alloy steels. These three components usually are present in corrosive gas-condensate fluids and are believed to be the cause of most of the damage to well equipment. Although the laboratory tests permitted only an approximate approach to exactness in reproducing the natural causes of corrosion, it seems likely that the results of the tests permit arranging the metals in the same order of relative resistance to corrosion as if the tests were made in the corrosive flow stream of a well. Alloy steels with the principal alloying constituent varied as to concentration over wide ranges were prepared especially for the corrosion tests in the laboratories of different manufacturers. The results of the tests provided information for selecting from each series of alloys the metal having optimum properties for service in high-pressure gas-condensate wells subject to corrosion.

The resistance to corrosion by carbonic and propionic acids and phenol of representative metals from each of the alloy classes is shown in Figure 1. The rates of corrosion, which are plotted on a logarithmic scale, are based on rates of weight



T 1932 C-30, N-10
C-4, 70, N-20
M C-33, N-67

loss measured in milligrams per square decimeter per day (mdd)* in the respective test mediums. Data reported on the loss of weight resulting from exposure of coupons of the metals in the corrosive mediums for 7 days before the coupons were cleaned and weighed are averages of 14 or more determinations. Other data shown in Figure 1 represent the results from one, or the average of several determinations.

Carbon steels used in the tests included commercial hot-rolled sheet steel identified as SAE 1005, which served as a standard to which the other metals could be compared as to their resistance to corrosion. Coupons of carbon steel J-55 were prepared by flattening and normalizing API grade J-55 tubing. On the basis of the results of the 7-day tests in carbonic acid, there is marked difference in the rates of corrosion of steels J-55 and SAE 1005. Rates of corrosion are in the same order as the respective carbon contents—the higher the carbon content the greater the rate of corrosion. Weight losses for carbon steel J-55 containing 0.46 percent carbon were about as great as for any of the alloyed steels tested. Conversely, steel SAE 1005, containing only 0.03 percent carbon, was found to be comparatively resistant to corrosion on the basis of short-exposure-period tests.

Data in Figure 1 show that the chromium content of a chromium steel must be 5 percent or more be-

fore such a steel will resist corrosion appreciably. A marked decrease in the rate of weight loss of chromium steels results when the chromium content is increased to 7.11 and 9.84 percent. As these steels were found especially resistant to pitting and other localized corrosion, the rate of weight loss is a reliable measure of their corrosion resistance. The most severe rate of corrosion measured on the 9.84-percent chromium steel by means of the 7-day test was 4.0 mdd, which corresponds to the removal of less than 0.001 inch of surface metal a year. This steel has the strength required for service in high-pressure wells; it can be tempered commercially to develop physical properties better than those required for API grade N-80 tubing.

8.6 Percent Nickel Steel

Of the nickel steels tested, the alloy containing 8.6 percent nickel is the most promising material for the manufacture of well tubing. Excellent physical properties can be developed in this metal; and, although coupons exposed for short period tests in carbonic acid showed localized corrosion, the surfaces of the coupons exposed in propionic acid and phenol were merely roughened. On the basis of the 7- and 140-day exposure tests, the rates of corrosion of the 8.6 percent nickel steel in carbonic acid were 260 and 32 mdd, respectively, corresponding to rates of removal of metal to depths of 0.047 and 0.006 inch a year respectively. There is indication that the relative corrosion resistance of nickel steels may be measured most reliably by long-period laboratory tests because of the protection afforded underlying metal by a covering of

*For carbon steels and other steels having a specific gravity of 7.86, multiply rates of weight loss in milligrams per square decimeter per day mdd by the factor 0.000183 to obtain the thickness in inches of the metal removed uniformly from the surface in a year (ipy).

corrosion products. Nickel steels containing less than 5 percent nickel were subject to severe pitting corrosion in carbonic acid.

Chromium-nickel steels showed excellent resistance to corrosion in laboratory tests. High cost and low tensile strength bar their use as tubing materials, although they may be suitable for the manufacture of special fittings.

Copper and Nickel Additions

Relatively small percentages of copper and nickel were alloyed into steel in systematically varied proportions to determine if the resultant metals would be resistant to corrosion by gas-condensate fluids. Altering the alloy content of the steels by increasing the nickel and copper content in the constant ratio of 2:1 had the effect of increasing their resistance to corrosion by carbonic acid and of increasing the tensile strength; increasing the copper content of the steel while maintaining nickel content constant had substantially the same effect. Both series of metals were, in general, satisfactory as to tensile strength, but the metals containing high percentages of copper lacked the physical properties required at milling temperatures in the manufacture of seamless tubing. The rates of weight loss in propionic and carbonic acids and the pitting corrosion that occurred in carbonic acid do not indicate that these low-copper-nickel steels would be satisfactory for the manufacture of tubing for gas-condensate wells subject to corrosion.

As indicated in Figure 1, the copper-nickel alloys are highly resistant to corrosion by carbonic acid and are satisfactorily resistant to propionic

acid. These alloys have a wide range of physical properties and may be suitable for the manufacture of special equipment to be used in flow streams where the fluid is corrosive.

Corrosion-resistant coatings and platings for steel also were tested. The zinc coating exhibited both anodic and cathodic characteristics, and although the coating may have minimized local attack of the steel the zinc was removed too rapidly by all corrosive mediums to warrant considering it a satisfactory protective material. Copper and nickel plates, which are cathodic with respect to steel, exhibited excellent resistance to corrosion, particularly by carbonic acid. Tests were made in all the corrosive mediums to determine the acceleration in corrosion of steel in areas where the test specimens were not covered by plate. It was found that for specimens having exposed steel surfaces equal to 7 percent of the total surface, the rate of corrosion in the exposed areas was 5 to 18 times the rate of corrosion of the same steel when it was not adjacent to a plated surface.

Sodium Chloride Test

Sodium chloride was added to propionic and carbonic acids in concentrations as high as 200,000 ppm to determine if acceleration of the rates of corrosion of carbon steel, 9.84-percent chromium steel, and 8.6-percent nickel steel would result. Rates of corrosion of the carbon and nickel steels were not changed appreciably. Rates of corrosion of the chromium steel were increased, though not to a serious degree, because they were quite low in the absence of sodium chloride. The maximum rate of corrosion for the chromium steel, 19.3

mdd as determined by the 7-day test in carbonic acid, corresponds to removal of the steel surface to a depth of 0.0035 inch a year.

The liquid-water phase of flowing gas-condensate fluid contains the corrosive components; and if metal surfaces can be maintained wet with liquid hydrocarbons to exclude water, corrosion of the metal can be prevented. Accordingly, tests were made to determine if aluminum, chromium, copper, nickel, and zinc in alloys or alloy steels would have the effect of promoting preferential wetting of a metal by condensate hydrocarbons. Two metals containing copper in high concentrations showed some tendency to attract hydrocarbons to surfaces previously wet with water, but no alloying material was found that caused gas-condensate hydrocarbons to displace the water phase entirely and cover the metal surface.

Hydrochloric Acid

Tests were made also to determine the resistance of the various alloys and alloy steels to attack by the hydrochloric acid used in treating wells. Measurements of the rates of weight loss at 130° and 300° F. indicated that sodium arsenite dissolved in the treating acid in a concentration of 0.80 percent provided a satisfactory control of corrosion. Rates of weight loss, from corrosion in the inhibited hydrochloric acid, of chromium and nickel steels and other metals suitable for the manufacture of tubing did not exceed 2000 mdd and averaged much less. There was no evidence of localized corrosion and the depth to which surface metal would be removed in a period of 24

hours at a corrosion rate of 1000 mdd uniform attack is 0.0005 inch.

Test Methods and Apparatus

Pressure cells and constant-temperature water baths used in determining rates of corrosion of steels and alloys in liquid mediums having the characteristics of fluids found to be corrosive in certain gas-condensate wells have been described.⁴ Figure 2 shows the equipment used and the procedure followed in removing from a cell the pint jars containing the metal coupons in a solution of carbonic acid. Suspended from a chain hoist between the water baths at the right of the operator is a cell on the outside of which are mounted jars containing metal coupons in solutions of propionic acid or phenol. The three aqueous solutions of carbonic acid, propionic acid, and phenol were the corrosive mediums used in determining the relative corrosion resistance of the alloy steels. The propionic acid and phenol solutions were each of 200 ppm concentration; the cells were charged with pure carbon dioxide gas under a pressure of 200 pounds per square inch absolute to provide the carbonic acid mediums. The cells are mounted in the water baths in such manner that the jars are beneath the surface of the water and are rotated at 9 rpm to provide agitation of the corrosive mediums. The water baths were maintained at 130° F.

Coupons were exposed to the corrosive solutions for periods of 1, 7, 28, 70, and 140 days, and the corresponding weight losses were determined to evaluate their relative resistance to corrosion. Figure 3 shows two different-size coupons suspended

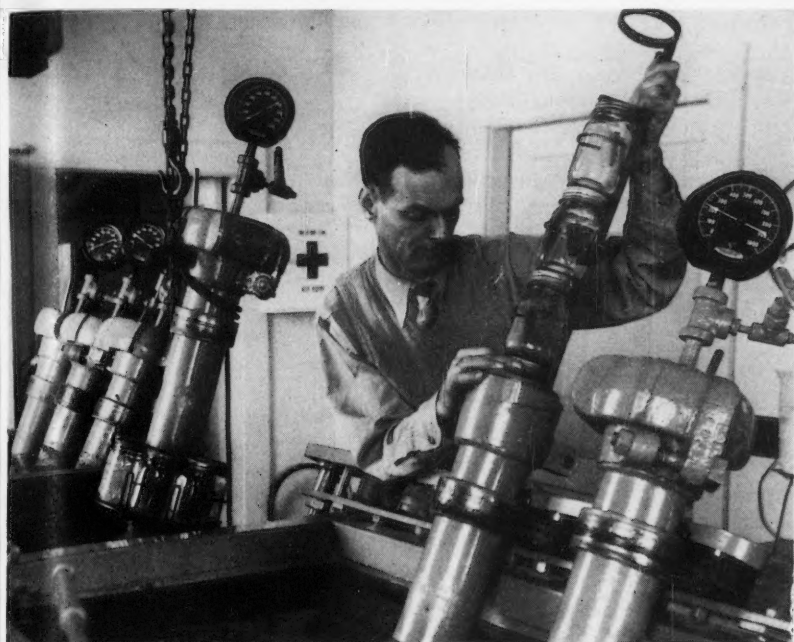


Figure 2—Removing from cells jars containing coupons which have been corroded by carbonic acid

from a glass support that fits inside a pint jar and a pint jar containing 400 cc of corrosive solution. The smaller of the two coupons is 5 cm by 3 cm in size and has a surface area of approximately 0.33 square decimeter. Coupons of this size were used for the 1- and 7-day exposure tests. The larger coupon, which was used for the 1-, 28- and 70-day tests, was 3 cm wide by 5.5 cm long to provide identification in addition to the numbers and letters stamped on one surface. The coupons were mounted on the cane glass support inside the jar in such manner that they were free to move as the jars revolved with the cell in the bath. A short length of glass tubing, slipped over the cane glass before it

was bent into shape, held the coupons apart. Exposing the two coupons in the same jar of corrosive solution assured that the results for the 7-, 28- and 70-day tests were obtained under identical conditions.

Rates of corrosion of a given metal usually were determined in the following manner: The 1-day tests were made on both the 5.0-cm and the 5.5-cm long coupons exposed in the same solution. The coupons were cleaned and weighed once a day for 4 days to provide a total of eight 1-day exposure measurements. The two coupons then were exposed in the same jar to determine the corrosion rate for 7-, 28- and 70-day exposures. The 5.0-cm long coupon, which was used to determine the

corrosion rate for the 7-day exposure, was cleaned and weighed once a week for 14 weeks to provide 14 measurements. The 5.5-cm long coupon was cleaned and weighed after a 28-day exposure in a corrosive solution and again after an additional 70-day exposure. A third coupon of the same metal was exposed in an identical solution in a separate jar for 140 days. The results for the 28-, 70- and 140-day tests usually represent one measurement for each exposure period.

Solutions Renewed Each Week

Corrosive solutions were renewed every 7 days regardless of the period of the test involved. For the tests in propionic acid and phenol, the coupons were transferred at the end of each 7-day period to a clean jar containing fresh aqueous solutions of 200 ppm concentration. For the carbonic acid tests, coupons were transferred every 7 days to a clean jar containing oxygen-free distilled water, which then was placed in the cell in an atmosphere of carbon dioxide under a pressure of 200 pounds per square inch absolute. Using fresh solutions at regular intervals assured an active corroding agent in the jars at all times and a minimum concentration of the soluble products of the corrosion.

Precautions were taken to exclude free oxygen from the corrosive solutions and from the jars and the steel cells in which the coupons were placed. Distilled water for the corrosive solutions was boiled to remove oxygen before corrosive ingredients were added. Solutions of propionic acid and phenol were

stored in stoppered carboys with the space above the liquid filled with nitrogen under a pressure slightly more than atmospheric. A siphon was used to transfer corrosive solutions from a carboy to a jar containing the coupons, and before the jar top was screwed down nitrogen was bubbled through the solution in the jars by means of a tube to remove atmospheric oxygen from the jar before it was sealed. Distilled water for the carbonic acid test also was boiled before it was placed in a jar with the coupons. A lump of solid carbon dioxide was dropped into the jar to evaporate with the jar top loosely in place so that atmospheric oxygen was driven from the jar before it was placed in the cell. Solid carbon dioxide also was placed in the bottom of the steel cell, just before the rack of jars containing the corrosive solutions and coupons were introduced, to drive oxygen from the cell and to build up a gas pressure of 200 pounds per square inch absolute in the cell. The precautions taken to remove free oxygen from the systems are believed to have been effective because a red color that would indicate traces of oxidized iron was never observed in the carbonic acid solutions at the conclusion of a test. Depending upon the alloy corroded, solutions of various colors were obtained from tests with the organic reagents. It is believed that these colors are the natural colors of the products derived from the corrosion reactions rather than colors developed by oxidation. For some alloys, the masses of red-colored products that accumulated greatly exceeding the quantities of iron oxide that could be formed



Figure 3—Coupons, glass suspension and pint jar of corrosive medium used in tests.

from only traces of oxygen in the jars.

An important part of the test procedure was to determine the loss of weight of coupons during their exposure in corrosive solutions. Most of the coupons were samples of sheet-metal stock sawed or sheared to size and smoothed with 120- and 320-grade aluminum oxide abrasive cloths. The finest practicable abrasives leave furrows and sharp ridges on the faces of the metals that are not only more susceptible to corrosion than flat surfaces but corrode at nonuniform rates. Therefore, the smoothed coupons were placed in an aqueous solution of propionic acid (200 ppm) at 130° F. for 24 hours to obtain a surface by corrosion of the type to be measured. After removing the products of corrosion from the coupons, they were weighed on a gravimetric balance in preparation for the corrosion tests. Although an attempt was made to cut the coupons to a standard

size, the dimensions of each coupon were measured by means of a vernier caliper to determine its exact surface area.

The removal of products of corrosion from coupons involved an initial scrubbing with a bristle brush and mild abrasives, followed by electrolytic cleaning with a hot, 10-percent solution of sulfuric acid. Figure 4 shows the equipment used in cleaning coupons. As soon as coupons were taken from the corrosive solutions at the end of an exposure period, they were washed and dried. Loose scale then was removed from the coupons by scrubbing them with a bristle brush using water and Sapolio, followed by water and Old Dutch Cleanser. The coupons then were hung on hooks of iron wire, which were the cathodes or negative poles of electrolytic cells containing sulfuric acid. The coupons were left immersed in the sulfuric acid bath for 10 minutes to remove remnants of scale and expose the

bright metal. The density of the electric current that flowed through the acid between the submerged coupon and a lead anode was 10 to 15 amperes per square decimeter of coupon surface. An inhibitor (Rodine liquid No. 77) was dissolved in the sulfuric acid in a concentration of 2 cc per liter of solution to minimize reaction between the metal and the cleaning acid. When the coupon was removed from the acid bath, it was immediately washed with water, given an additional scrubbing, and then dried by means of a jet of compressed air before weighing. At times it was necessary to repeat the cleaning process to remove all the scale that had accumulated on the surface of a coupon. The metal loss, which averaged, for a 3 by 5 cm coupon, 1 mg for each cleaning treatment in the acid bath was considered in computing the weight loss incurred during the corrosion test.

Method of Weighing

The coupons were weighed on a gravimetric balance with an accuracy uncertainty of ± 1 mg. The accuracy of this part of the procedure does not, of course, necessarily indicate the over-all accuracy of the corrosion-rate determination for a particular exposure period. The impossibility of cleaning all corrosion products from pits in the coupon surfaces and the accidental removal of flakes of metal from a coupon during the cleaning procedure are examples of sources of error of serious consequences. There also was the difficulty of reproducing weight losses of similar coupons tested under identical conditions. Conse-

quently, it was the general practice to report the average of a number of determinations rather than the result of a single determination if test results were available. In any event, the rates of corrosion given in this report are limited to two significant figures unless the first figure is unity, in which case three significant figures are reported.

Measures of Resistance to Corrosion

Although efforts were made to develop corrosion-test methods that would duplicate conditions in gas-condensate wells, the limitations of laboratory facilities and operating time permitted only a practicable approach to exactness in reproduction of the natural causes of corrosion. The composition of well fluids, the complicated phase phenomena, and the nature of the movement of the liquid and gaseous phases that prevail in high-pressure wells are not reproducible on a reduced scale in laboratory equipment. A series of metals subjected to a laboratory corrosion test would not necessarily corrode at the same rate as they would in wells. There is the definite possibility, however, that the respective rates of corrosion of two or more metals as determined by laboratory tests and by exposure to the flow; stream of a well would be of the same relative magnitude. Therefore, if different metals, including a standard metal such as is used in the fabrication of well equipment, are subjected to the same laboratory test, the results of the test should afford a basis for determining which metals would be more corrosion-resistant in a well. The probable

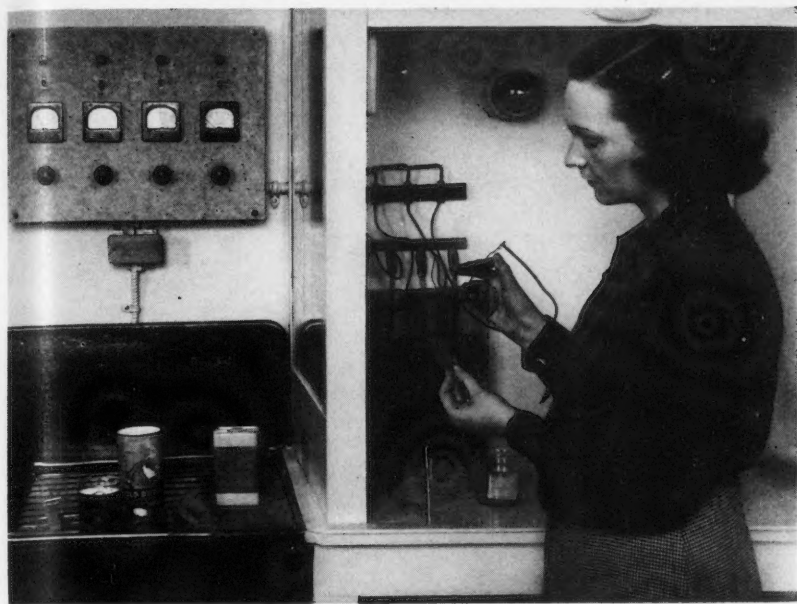


Figure 4—Cleaning products of corrosion from coupons by means of an electrolytic bath.

service life of equipment made from a metal selected on that basis would be indicated by comparison of the laboratory-determined corrosion resistance of the metal under consideration with that of the standard metal which had been used in wells.

In this investigation the results of 7-day-exposure tests using solutions of propionic acid, carbonic acid, and phenol have greater weight in determinations of the relative corrosion resistance of different metals than those for tests involving other periods of exposure. The weight-loss measurements for the 7-day tests were repeated at regular and convenient intervals to obtain an average of 14 to 28 determinations. However, the 1-, 28-, 70- and 140-

day tests, each of which involved less repetition of measurements than the 7-day test, served the important purpose of indicating the effect of length of exposure on the corrosion resistance of the metals. The weight loss of a metal for a 7-day period, no matter how accurately determined, might not be a reliable index of its resistance to corrosion in actual service if the resistance to corrosion in service is due to formation of a cumulative protective film on the surface of the metal. Such a metal in service would be more resistant to corrosion than the results of the 7-day tests would indicate. Conversely, a pitting corrosion might occur of such nature that the rate at which metal was lost would

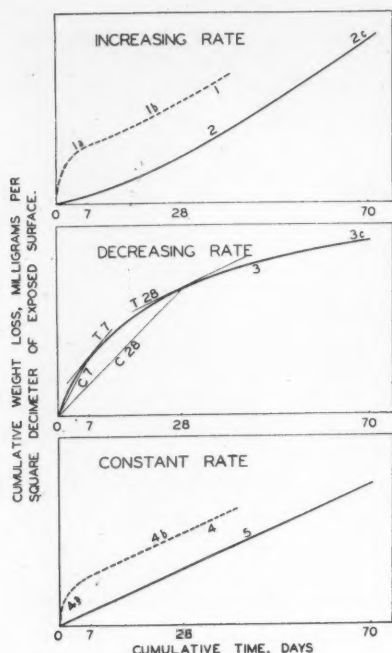


Figure 5—General relation between cumulative weight loss from coupons and period of exposure in corrosive mediums.

increase with time of exposure to the corrosive mediums, and the rate of weight loss indicated by a 7-day test would be less than actually would occur in an indefinite period of service.

Three general relations between cumulative weight loss and period of exposure are illustrated in Figure 5. If the weight of the metal converted to corrosion products each day from a unit area of exposed surface remains the same with passage of time, the rate of corrosion is constant. A linear relation like that illustrated by line segment 5 in the lower section of Figure 5 can be

used to record the progress of such corrosion. If, owing to the nature of the corrosion, the rate at which metal is converted into corrosion products each day increases, curve 2 in the upper section of Figure 5 describes the relation between cumulative weight loss and time. The rate of corrosion need not increase indefinitely to be defined as increasing; at some time the curve would tend to become linear, as indicated by portion 2c. An accumulating film or scale of corrosion products that tends to protect underlying metal against corrosion would cause the corrosion rate to decrease with time, as indicated by curve 3. The rate of corrosion might decrease to negligible values but in general would approach a constant value and gradually assume a linear shape, as indicated by curve portion 3c.

Corrosion Rate High First Day

In testing the various metals, it was found that a plot of weight-loss data did not always trace definite curves, such as curves 2, 3, and 5 of Figure 5. Despite the practice of preparing the surface of the coupons for test by a corrosion process, the rate of corrosion measured in the 1-day test frequently was high compared to the rate of corrosion measured in the 7-day test. For many coupons, the curve of cumulative weight loss would rise rapidly with time for the first day or so, as illustrated by curve portions 1a and 4a, and thereafter might indicate either an increasing rate of corrosion (curve portion 1b) or a constant rate of corrosion (curve portion 4b). In such cases the relation between weight loss and time was classified on the basis of

the shape of the curve which eventually predominated.

The rate at which a metal was corroding at any given time could be determined from the slope of the curve showing the relation between cumulative weight loss and time of exposure. With reference to curve 3 of Figure 5, the slope of tangent T7 shows the rate of corrosion after 7 days of exposure, and the slope of tangent T28 shows the rate of corrosion after 28 days of exposure. The rate of corrosion is decreasing with time, and the slope of a tangent at a point on curve 3 corresponding to 70 days of exposure therefore would be less than that of tangents T7 and T28. Although the use of tangent slopes provides a sound theoretical means for expressing rates of corrosion at particular times, tangents are subject to practical disadvantages and were not used in this report. One disadvantage is that data must be obtained to locate the entire curve before the slope at any point on the curve can be measured and the corrosion rate evaluated. Another disadvantage is that plotted corrosion data frequently are not regular enough to permit fitting them with curves, such as curves 2, 3, and 5 in Figure 5. For example, curve segments 1a and 4a show relatively high rates of corrosion for the first day that would not be indicated if the measure of the rate of corrosion at the end of 7 days was the slope of a line tangent to the curve at that point. Such initial high rates of corrosion may or may not be significant in the service life of a metal; nevertheless, it is desirable to report the result of a corrosion test in such

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Characteristic Change in Rate of Corrosion
of Steels With Period of Continuous
Exposure

Metal Class	Type of Rate Change in Indicated Medium		
	Propionic Acid	Carbonic Acid	Phenol
Carbon steels	Increasing	Increasing	Increasing
Chromium steels	Constant	Constant	Constant
Nickel steels	Increasing	Decreasing	Constant
Chromium-nickel steels	Indefinite	Indefinite	.....
Copper-nickel steels	Increasing	Decreasing	.....
Copper-nickel alloys	Constant	Constant	.....

manner that all the corrosion occurring during a specified period of exposure is accounted for.

The method used by the authors for reporting test data is illustrated by curve 3, Figure 5. It is assumed that curve 3 was located by drawing it through points representing weight-loss values determined by the 1-, 7-, 28-, and 70-day tests—Figure 5 is not drawn to show results for 140-day tests. Chords C7 and C28 are drawn to the points for the 7- and 28-day tests, respectively. The slopes of the chords, expressed in milligrams of weight loss per square decimeter of metal surface per day of exposure (mdd), are the measures of the rates of corrosion for the corresponding tests. The slopes of similar chords to the data points for the 1-, 70- and 140-day tests would provide the rates of corrosion to be reported for those tests. The example of the slopes of chords for expressing corrosion rates can be applied as well to curves 1, 2 and 4. Chords need not be applied to line 5 passing through the origin because rates of this type of corrosion measured for different periods of ex-

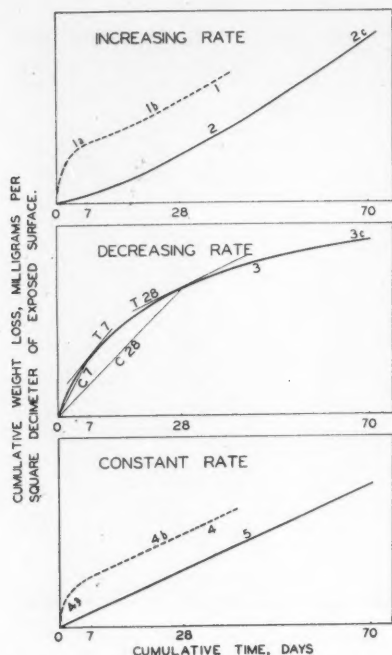


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posure are identical within the limits of experimental error, and chords would coincide with the line.

It was not the practice to use curves like those shown in Figure 5 to smooth the values of measurements of weight losses and then determine rates of corrosion from the slopes of chords drawn to the curves at points corresponding to the test-time intervals. The datum point is located by multiplying the value of the measured rate of corrosion by the number of days of exposure involved in the test, and the test result reported is the measured rate and also the slope of the chord drawn to the datum point whether or not the point falls on the smooth curve. Curves like those in Figure 5 are drawn to determine graphically if the rate of corrosion is increasing, decreasing, or constant with time of exposure.

The importance of knowing the shape of the corrosion curve will become evident as the results of corrosion tests on the metals are discussed. Table I is a summary of the information obtained on the shapes of the cumulative-weight-loss curves. As shown in the table, the rate of corrosion of the carbon steels increased with time of exposure in the three corrosive mediums. Although the shape of the curves for chromium steels depended somewhat on the concentration of chromium, the relation between rate of corrosion and time was linear for steels containing 5 percent or more chromium, indicating that for such steels the rates of corrosion were constant irrespective of the period of exposure and the accumulation of a film of corrosion products. Single

laboratory determinations of rate of weight loss involving different periods of exposure should be equally reliable for indicating what can be expected of the chromium alloys in actual service, because the scouring action of flowing fluid streams would not affect the rate of corrosion.

The rate of corrosion of nickel steels in propionic acid increased with time of exposure, and in a solution of phenol the rate was constant. Nickel steels showed relatively high initial rates of corrosion in carbonic acid; but, with passage of time, the rates decreased possibly as the result of cumulation of a protective film on the metal surface. By reason of this characteristic of nickel steels it may be that their resistance to corrosion should be compared with that of other metals on the basis of the laboratory tests involving exposure periods of 70, 140, or a greater number of days.

Chromium-nickel steels of the stainless type were highly resistant to the corrosive mediums, and coupons of such steels lost so little weight during the exposure tests that the characteristic shape of the cumulative-weight-loss curves could not be determined.

Corrosion rates of copper-nickel steels showed a definite tendency to increase with time of exposure in propionic acid and to decrease in carbonic acid. Nickel steels showed the same characteristics, but the increasing and decreasing tendencies were not so pronounced and consistent as they were in the steels containing copper and nickel. A factor that may have some significance is that alloys containing 33 percent or

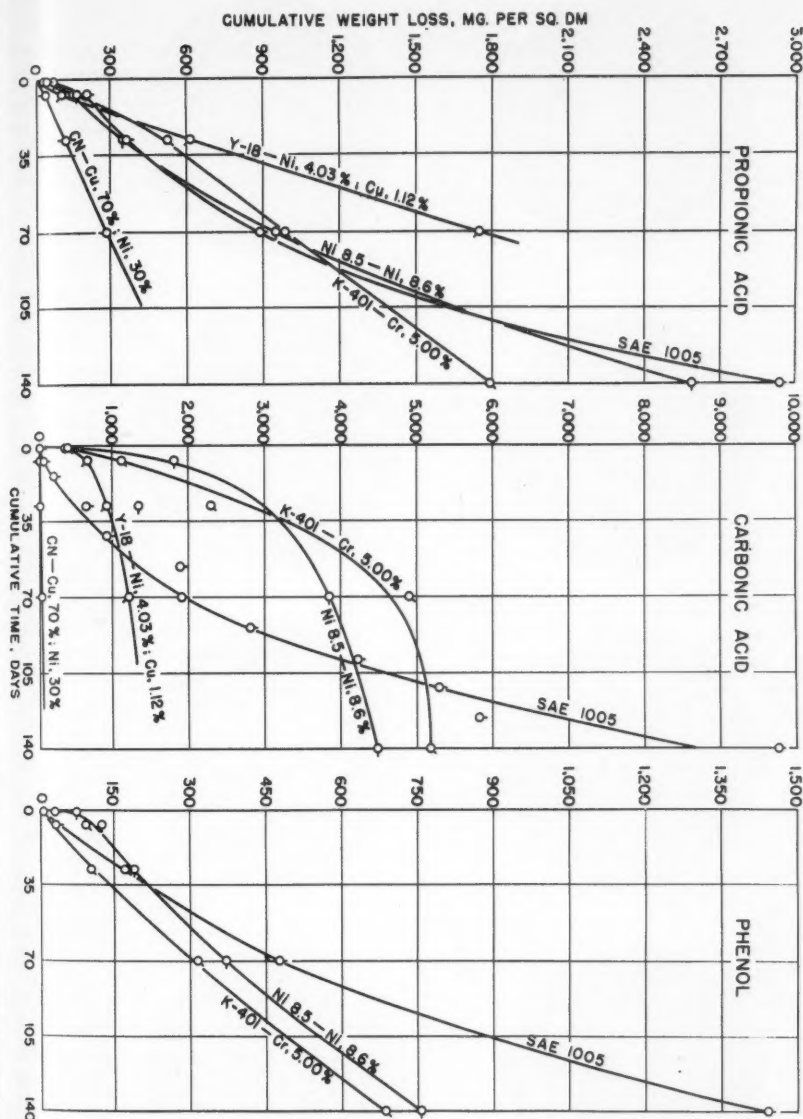


Figure 6—Characteristic relation between weight loss and period of continuous exposure for representative metals.

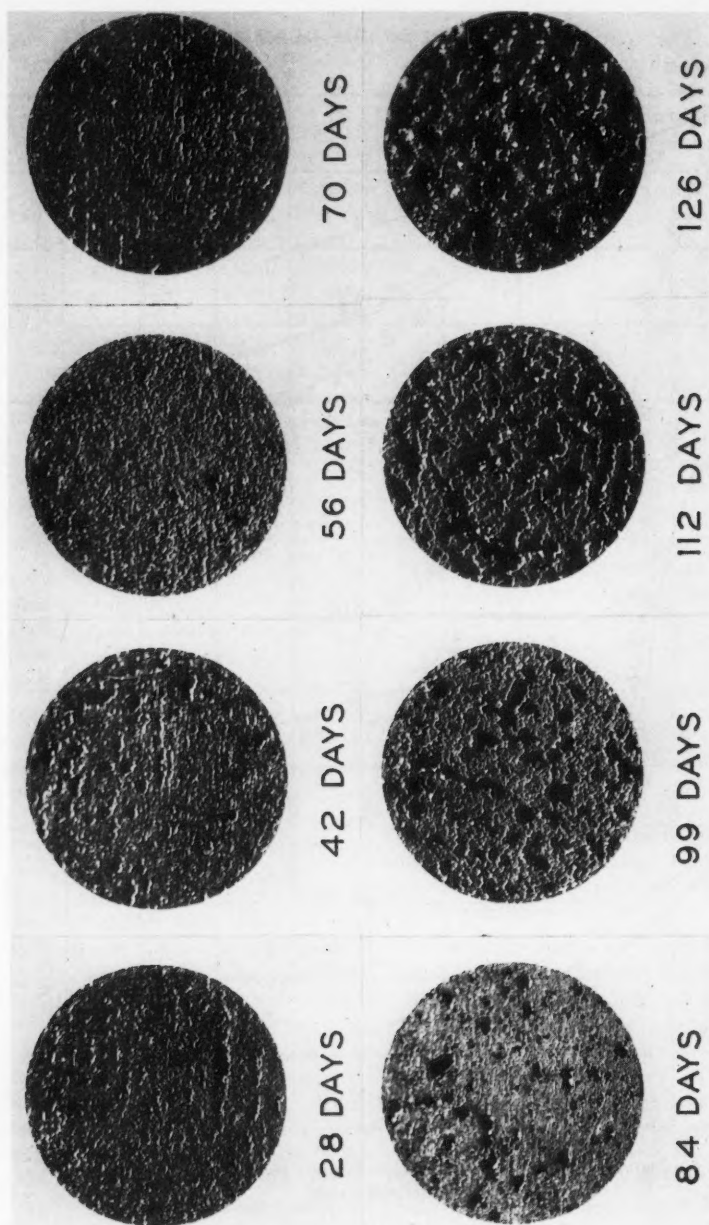


Figure 7—Progress of pitting of SAE 1005 steel exposed in carbonic acid. Original magnification 15X.

more of copper are susceptible to moderate corrosion by propionic acid but markedly resistant to corrosion by carbonic acid. Alloys of copper and nickel in a wide range of proportions had low rates of corrosion that were constant and independent of the period of exposure.

In Figure 6 are curves showing the relation of cumulative weight loss to period of exposure for metals representative of the classes listed in Table I. The coordinates of Figure 6 are the same as those of Figure 5 and the curves shown in Figure 6 have the characteristics of the schematic curves in Figure 5. The curves of Figure 6 that illustrate the results obtained when propionic acid was the corrosive medium indicate that a selection of the metals for maximum corrosion resistance can be made without regard for the test period of exposure. Copper-nickel alloy CN is the most resistant and copper-nickel steel Y-18 is the least resistant to corrosion in propionic acid for all periods of exposure. Carbon steel SAE 1005, nickel steel Ni 8.5, and chromium steel K-401 (5.00 percent chromium) are approximately equally resistant to corrosion for exposure periods up to 70 days; and, on the basis of longer test periods, the chromium steel appears only slightly more resistant to corrosion than the other alloy steels.

The curves based on corrosion tests made in a medium of carbonic acid indicate that the choice of metals for resistance to corrosion depends to a considerable extent on the period of exposure selected as the basis for comparison. On the basis of the 7- and 28-day tests, carbon steel SAE 1005 exhibits more

resistance to corrosion than copper-nickel steel Y-18, nickel steel Ni 8.5, and chromium steel K-401. On the basis of the 140-day test, however, carbon steel SAE 1005 is subject to higher rates of corrosion than the other steels, and the relative rates of corrosion of the chromium and nickel steels are the reverse of the relative rates determined by the 7-day tests.

Distribution of the weight loss also is an important consideration in judging the relative corrosion resistance of these metals to carbonic acid. Figure 7 is an assembly of photomicrographs of the surface of coupons used in obtaining data for plotting the curve in Figure 6 for carbon steel SAE 1005. The photomicrographs were made after the coupons had been cleaned electrolytically. The coupon exposed in the corrosive solution for 28 days shows the beginnings of a pitting corrosion. The depth of the pits increased and new pits formed; until, at the end of 70 days, the surface was considerably roughened by cell-type corrosion attack. The coupon exposed for 84 days shows marked increase in the size of the pits, and after 99 days in the carbonic acid approximately 50 percent of the surface was corroded away. A portion of the original flat surface remained at the end of 112 days, but after 126 days the entire surface was roughened and irregular. Other laboratory tests have shown that coupons of the low-carbon steels corrode more or less uniformly once a certain roughness of the surface is attained; the thickness of a sheet-metal coupon can be reduced by corrosion from 2 mm to less than 1 mm with-

out the coupon being completely penetrated. The pitting corrosion which occurred in carbonic acid was accompanied by the formation of a corrosion product identified by X-ray diffraction analysis as ferrous carbonate. (A similar analysis of the corrosion product from a fitting on a gas-condensate well showed it to be ferrous carbonate also.)

Chromium steel K-401 and nickel steel Ni 8.5 were roughened slightly by a pitting corrosion when exposed in carbonic acid. Copper-nickel steel Y-18 was subject to such localized attack by the acid that it would be of doubtful worth in gas-condensate well service despite its relatively low cumulative weight loss. The cumulative weight loss for copper-nickel alloy CN was low and it was not observed to be subject to a pitting corrosion; its high cost, however, would eliminate this metal for consideration as a material for the manufacture of tubing.

It is known that carbon steels containing 0.25 to 0.46 percent carbon in service in gas-condensate wells are subject to severe pitting corrosion. As will be discussed later, the cumulative weight loss of coupons of API-grade tubing J-55 exposed in carbonic acid for 7 days was much higher than the weight loss from carbon steel SAE 1005. On the basis of the 140-day test, carbon steel SAE 1005 would be eliminated from the list of metals for which the results of the carbonic acid corrosion tests are shown in Figure 6. Unless it should be proved advisable to decrease the carbon content of steels to gain corrosion resistance at the cost of loss in physical properties, carbon steel SAE 1005 would be eliminated because of its low tensile

strength despite its relatively high resistance to corrosion as determined by the 7-day test in carbonic acid.

Chromium steel K-401, containing 5.00 percent chromium, and nickel steel Ni 8.5, containing 8.6 percent nickel, remain for comparison. On the basis of the 7-day test in the carbonic acid medium, the rate of corrosion of the chromium steel is 62 percent of the rate of corrosion of the nickel steel; on the basis of the 140-day test, the rate of corrosion of the chromium steel is 16 percent higher than the rate of corrosion of the nickel steel. Although the curve for chromium steel K-401 does not show it, the relation between time of exposure and cumulative weight loss for most of the chromium steels tested was linear (rates of corrosion constant with time), and not much protection against corrosion would be expected for this metal from a deposited film of corrosion products. Nickel steels generally show decreasing rates of corrosion with accumulation of a film or scale of corrosion products. However, in the laboratory tests nickel steels have been found more susceptible to pitting corrosion than chromium steels, and somewhat greater metal losses could be tolerated from chromium steels than from nickel steels if the two were compared for corrosion resistance on the basis of test results obtained by exposures of 70 or more days in the corrosive solutions. Considering all the information obtained by the tests in carbonic acid, the steel containing 8.6 percent nickel apparently would be a better material for resisting corrosion in gas-condensate wells than that containing 5.0 percent chromium. Test

results in all three of the corrosive mediums are presented later, showing that increase in the chromium content of the chromium steels from 5.0 to 7.11 percent materially increases their resistance to corrosion, particularly in carbonic acid.

The corrosion resistance of only three of the metals was determined in a solution of phenol. Test results illustrated in Figure 6 show that consideration of the period of exposure is of some importance in judging the relative corrosion resistance of the metals tested. On the basis of the 7-day test, carbon steel SAE 1005 is as good or better than the chromium and nickel steels for resisting corrosion. For 140 days of exposure in a phenol solution, the carbon steel showed rates of corrosion approximately twice as great as the rates determined for the chromium and nickel steels. There was no marked difference in the rates of corrosion of the chromium and nickel steels at any period of exposure; but, in general, the steel containing 5.0 percent chromium appeared to be slightly more resistant to corrosion. Pronounced pitting corrosion was not characteristic of the tests in phenol, and the relative merits of the metals tested in that medium therefore could be judged

by their respective losses of weight.

Results of corrosion tests on metals representing five of the six classes of metals discussed in this report are shown graphically in Figure 6 to illustrate the significance of all of the reported corrosion data. Of the steels compared in Figure 6, the 5.0 percent chromium steel was found to be the most resistant to corrosion in propionic acid and phenol solutions. The 8.6-percent nickel steel was superior to the others on the basis of tests in carbonic acid. These metals exhibit similar corrosion resistance, but there is some question as to whether the results of the short- or the long-period exposure tests should be used as criteria of their relative resistance to corrosion. Also it is not certain which corrosive medium provides test conditions most nearly representative of those that prevail in gas-condensate wells subject to corrosion. However, as a result of the laboratory tests, measures of resistance to corrosion have been developed that appreciably narrow the limits of uncertainty and reduce the cost of tests that must follow with full-scale equipment at wells in the field where the relative resistance to corrosion of the metals will be finally determined.

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Editor's note: The second and concluding part of this article will be printed in next month's CORROSION.

Cathodic Protection of Casings in Loudon Pool*

By S. P. Ewing* and J. F. Bayhi*

Summary

THIS investigation was conducted in an effort to determine whether or not appreciable corrosion was occurring on insulated casings and, if so, whether cathodic protection could be used to prevent external casing corrosion; and to determine the most economical and feasible method for applying this protection. Results indicate that casings which are approximately 1500 feet long can be protected by a current of from 1.0 to 1.5 amperes, and that the anode should be located approximately 200 feet or more from the well. On Devonian wells, which are cased to approximately 3000 feet, the protection appears to extend to about 2000 feet.

These conclusions are based on short-time applications of protective current to wells in the Loudon Pool. Further long-time studies of the effect of the protective current are desirable. It is believed that the results are applicable to other similar fields.

Introduction

The discovery well in the Loudon Pool was completed in March 1937. During the next three years about

1800 producing wells were completed. These are all shallow wells, about 1500 feet in depth, and it was the usual practice to use 6-inch casing of either 13.51 or 14.64 pounds per foot, weld the joints and cement the casing all the way to the surface. Since 1941, about 130 wells have been drilled to deeper producing horizons. At present, the Authors' company is operating 1242 producing wells and 98 gas injection wells in this field on an area about 6 miles wide and 20 miles long. This represents about 67 percent of the total number of wells in the pool, and they produce about the same percentage of the total production from the pool. It is estimated that production will continue for approximately 50 years in at least part of the field.

Casing corrosion at Loudon was first discovered and reported by R. A. Hammond in 1944.** The first casing leak occurred in 1941, after 34 months' service and the number of leaks per year increased to a maximum in 1945. Nearly all of these leaks have occurred in the Tar Springs sand, which is saturated with salt water and is at an approximate depth of 1200 feet. In Hammond's report it was shown that by temporarily disconnecting flow lines

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** Intra-company Report.

there was a rather large current flow from the flow lines to the wells. Potential drop measurements along the casings, made by our laboratory in 1945, showed that much of the current left the casing in the Tar Springs sand. At that time, a program of insulating all wells from the flow lines was started. The work was completed early in 1946. A few leaks have occurred since the insulation was installed, but not enough to establish a future leak frequency with any precision. In some cases it has been possible to show that the leaks actually occurred prior to installing the insulation, and in one case the insulation was found to be defective.

While the actual number of leaks is small considering the footage of pipe as compared with many surface pipelines, the expected long life of the wells and the high cost of a leak makes it economical to go to considerable expense in eliminating future leaks.

There is no good reason for believing that casing corrosion is more severe in Loudon than in other fields but, of course, leaks would appear earlier and more frequently on the thin-walled casings which were used at Loudon.

Measurements on the Surface Pipe System

Why the Surface Pipes Must Be Considered

In order to apply cathodic protection it is necessary to determine the current required to protect a typical well, and to determine a suitable location for the anode so that this current will be properly distributed

along the length of the casing. In a complicated system of casings, surface pipelines and other structures, as the Loudon Pool, a great number of circuit arrangements are possible. In such a system one must be reasonably certain that none of these structures is accidentally made anodic by the applied current. A few of these possibilities are the following:

1) Use abandoned wells and scrap pipe placed in salt water storage basins for anodes to protect both well casings and pipelines, the pipelines being used to return the current from the well casings.

2) Use large low-resistance anodes as in (1), but collect the current from the wells with copper wires on the power poles and protect only the well casings, since they are the only structures which require protection. Perhaps the 440-volt, a-c wires could be used for this purpose.

3) Use scrap pipe anodes with rectifiers near the individual wells and protect only one well with each anode. This will involve considerable expense in the installation of anodes and the purchase of a large number of rectifiers.

4) Use magnesium anodes near individual wells, and protect only one well with each anode. In this case the principal cost will be the magnesium anodes.

Measurements on Surface Pipelines

To try out the possibility listed under (1) above, some measurements were made on one lease, which was chosen because of the simplicity of the pipe system, and because one

well was abandoned. When one ampere was drained from the header near the lease tanks, using the abandoned well as an anode, potential drop measurements along the flow lines near the header gave the calculated current changes shown in Figure 1 when the anode circuit was closed. During these measurements, the flow lines were insulated from the wells. The results account for most of the applied current, and are self consistent, but they show wide differences in the amount of current collected by the three flow lines. A high resistance joint was found between the pipe contacts on the line to well No. 4.

At another time a current of 8 amperes was drained from the header, and ammeters were connected between flow line and casing at each of the three wells. A negligible, but measurable current, flowed from wells No. 1 and 4, and a current of 3.5 amperes, which dropped to 2 amperes in $1\frac{1}{2}$ hours, flowed from well No. 2.

The only reasonable explanation of these results is that there are numerous high-resistance joints in the surface pipe system. The results indicate this method is an undesirable protection scheme.

Measurements between Wells and Flow Lines

Measurements of 1) short circuit current between well and flow line,

2) resistance between flow line and ground, and 3) resistance between well casing and ground were made on 15 wells scattered over the field. A summary of the results is given in Table 1. It can be seen from the table that there is only a moderate variation in the open-circuit potential (potential compared to calomel electrode) and in the resistance between casing and ground, (well to ground). Hence, it may be that the large observed variation in short-circuit current is caused principally by the large variation in flow-line resistance to ground. This is shown when flow-line resistance is plotted against short-circuit current in Figure 2.

These results also indicate that there are insulating or high-resist-

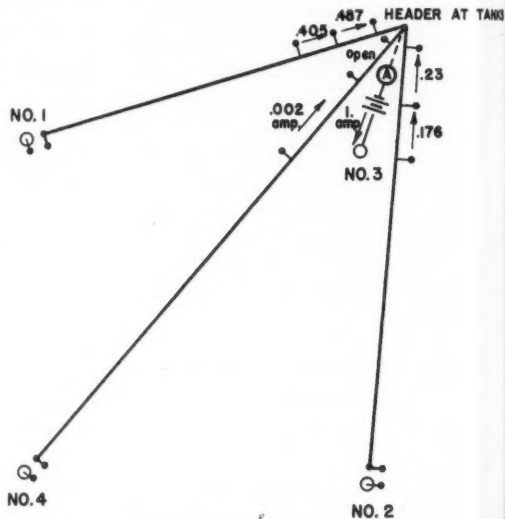


FIGURE 1— CURRENTS IN FLOW LINES WITH ONE AMPERE DRAINAGE OF HEADER TO NO. 3 WELL.

ance joints in some of the flow lines. If these lines are to be used to distribute current to the wells, all of these joints must be located and bonded. Otherwise, it would be extremely difficult to get proper distribution of the current to the wells, and even if this were accomplished without bonding the high-resistance joints, current would be shunted around the joints and cause rapid corrosion on one side of the joint.

Discussion of Cathodic Protection Circuits

Rough calculations using available pipeline maps, indicate that the total external area of the gas injection lines, gas gathering lines, and oil lines is about 1,500,000 square feet, which is equivalent to over 300 miles of 3-inch pipe. The area of the well casings is about 4,500,000 square feet or three times the surface pipe area. The total current required to protect the surface lines is probably greater than the total current required to protect the wells, because higher current densities would be needed on the surface pipes. Since the cost of leaks on the surface pipe system is not a large item, the added cost of cathodically protecting the surface pipes might result in very little gain. It, therefore, seems unnecessary to give further consideration to the surface pipe system as a part of this cathodically protected system.

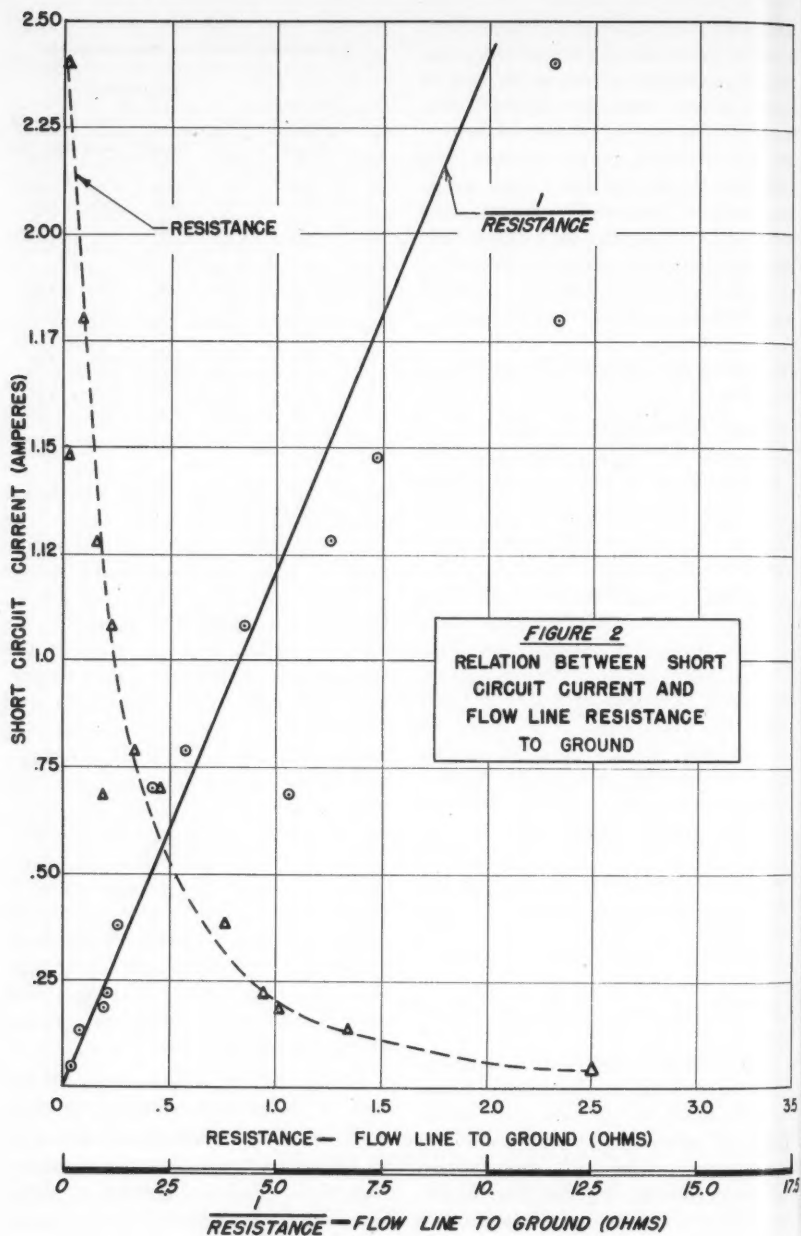
It would be possible to use abandoned well casings for anodes or to install anodes in or near salt water ponds or other places where the soil resistivity is low, and thus obtain low resistance to ground at lower cost. Fewer large rectifying units

TABLE 1
Wellhead—Flow Line Measurements

Well	Potential Compared to Calomel Electrode (Volt)	Short Circuit Current (Amps)	RESISTANCE		Potential Well to Flow Line (Volt)
			Well to Ground (Ohm)	Flow Line to Ground (Ohms)	
B	0.98	0.13	0.087	2.50	0.331
E	0.74	0.056	0.098	3.92	0.222
F	0.79	0.054	0.12	4.78	0.261
G	0.75	1.08	0.057	0.234	0.300
H	0.72	1.48	0.072	0.024	0.117
I	0.77	0.212	0.112	0.95	0.139
J	0.79	1.80	0.041	0.085	0.227
K	0.79	0.70	0.055	0.463	0.350
L	0.86	0.38	0.032	0.768	0.303
M	0.79	0.69	0.040	0.196	0.157
N	0.79	0.79	0.053	0.346	0.310
O	0.77	0.183	0.098	1.02	0.200
P	0.75	1.28	0.031	0.159	0.246
Q	0.81	1.54	0.050	0.135	0.276
R	0.76	2.40	0.040	0.086	0.277

would be cheaper than numerous small units of the same capacity. The principal disadvantage of this plan is that large currents would flow for considerable distances through the earth, and much of this current would find its way to the surface pipe system. In order to prevent damage to surface pipes and tank bottoms it would be necessary to install bonds at pipe crossings, and probably bond most of the flow lines to wells. To be sure that there are no anodic areas on surface structures, it would probably be necessary to cathodically protect most of them; so it would be necessary to make a continuous network by cross-bonding these structures. Hence, this plan has little advantage over cathodically protecting the entire surface system.

Protection of well casings by the use of individual anodes for each well has the following advantages: 1) Potential drops through the earth and their possible hazard to other structures are reduced to the lowest



possible value, because the anodes will be located as far as possible from pipelines, the currents are small, and appreciable drops through the earth are restricted to a small region; 2) the installations are all similar and the equipment for all wells would be identical, hence the installation procedure is straight forward and requires a minimum of supervision and testing. The large number of required units would permit working out a design which is satisfactory and low in cost. Rectifiers throughout the field would cause an increase of about one percent on the load of the generators which supply power to the pumps.

Methods for Determining Current Required for Protection

Table 1 shows that the resistance to remote ground of the well casings is more or less constant from well to well, so it is assumed that all wells are alike as far as cathodic protection is concerned. It is clearly out of the question to guess at current requirements and anode positions in this case, where there is no previous experience and where so many similar units are involved. The problems then are to determine the current required, the location for the anode in order to obtain reasonably good distribution of this current along the casing.

Two ways were used to determine current requirements. These are: 1) IR drop measurements along the casing and 2) current-potential measurements on the external surface of the casing. The first method also provides a means for determin-

ing the current distribution along the casing.

IR Drop Measurements Along the Casing

Consider the problem of determining the current flow to or from a uniform linear structure of resistance, ρ , per unit length by measurements of the IR drops along the structure.

The drop between any two points on the structure is:

$$\int_{X_1}^{X_2} I \rho dx = \Delta E \quad [1]$$

where the current $I = f(x)$, is the current at any point in the structure and ΔE is the drop in potential. The current flow to or from the structure in amperes per unit length is:

$$i = \frac{dI}{dx} \text{ so that } I = \int i dx \quad [2]$$

where i = current flow to or from the structure

I = current at any point on structure

x = distance from the surface

Combining [1] and [2],

$$\Delta E = \rho \int_{X_1}^{X_2} \left[\int i dx \right] dx \quad [3]$$

If ΔE is the drop from the surface to any point x in a well casing, integration of [3] gives,

$$\frac{d^2 (\Delta E)}{dx^2} = \rho i_x \quad [4]$$

Hence, a continuous record of the second derivation of the IR drop, is a measure of the current flow to or from the casing at every point. It might be possible to make such a measurement were it not for the fact that in any reasonably long length of casing, the change in the drop with time makes such a measure-

ment impracticable, aside from other experimental difficulties.

By changing the integration limits, the equation for a double probe of span, l , is found to be:

$$\frac{d^2(\Delta E)}{dx^2} = \rho \left[i \left(x + \frac{l}{2} \right) - i \left(x - \frac{l}{2} \right) \right] \quad [5]$$

This means that if i (current flow to or from structure) were known at $x - \frac{l}{2}$, the value at $x + \frac{l}{2}$ could be determined from the second derivation of the drop. In the same way, the value of i at $x - \frac{l}{2}$ depends on the value at $x + \frac{l}{2}$ and so on, to the top of the casing. Hence, the double probe does not remove the essential difficulty which we found with the single probe. It is believed that this analysis shows that a continuous record of the drop along a well casing would be of rather limited value and probably not worth the effort required to get it.

Another way to look at the problem is to assume that I in [1] is an average value between x_1 and x_2 .

$$\text{Then} \quad \Delta E_x = I_x \rho l \quad [6]$$

$$\text{and } i_x = I \left(x + \frac{l}{2} \right) - I \left(x - \frac{l}{2} \right) =$$

$$\left[\Delta E \left(x + \frac{l}{2} \right) - \Delta E \left(x - \frac{l}{2} \right) \right] \frac{1}{\rho l} \quad [7]$$

These relations indicate that i_x along the casing will be fixed with the greatest precision if the span, l , is made as short as possible.

Advantages of Double Contact Probe Measurements

IR drop measurements were made with a Brown potentiometer. The sensitivity of the instrument was in-

creased beyond the manufacturer's recommendations by selecting a tube with an exceptionally low noise level, and checking the zero on each measurement. With this arrangement, potentials can be measured to a precision of two microvolts through the well logging cable, which was used for making the measurements. This made it possible to detect a current of 10 milliamperes in the Loudon casings with a span of 10 feet. A double contact probe has the following advantages over a single contact with the other terminal at the wellhead:

1) Each potential reading indicates the current in the 10-foot section alone, and is not superimposed on the drop above the electrode.

2) As the contacts are only 10 feet apart, thermal effects are negligible below the wellhead.

3) The leads are parallel and similar throughout their lengths, which helps to balance out extraneous effects. Hence, even if equal precision could be obtained with a single contact, which is doubtful, all of the above effects would seriously affect the results.

Measurements at Loudon were usually made at intervals of 50 feet along the casing. Measurements of the overall drop along the casing were also made with various applied currents from various anodes. Figure 3 shows the equipment used in making the measurements.

Sources of Error in Double Probe Measurements

In order to obtain IR drop measurements that are reproducible, it is necessary to penetrate any scale on the pipe surface and obtain good me-

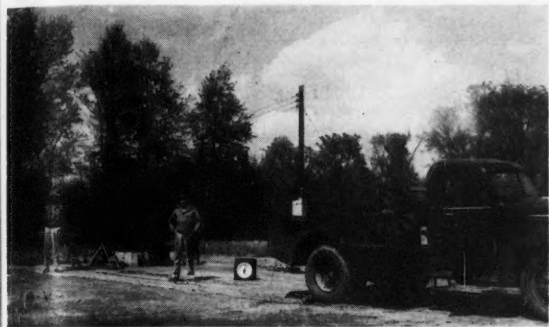
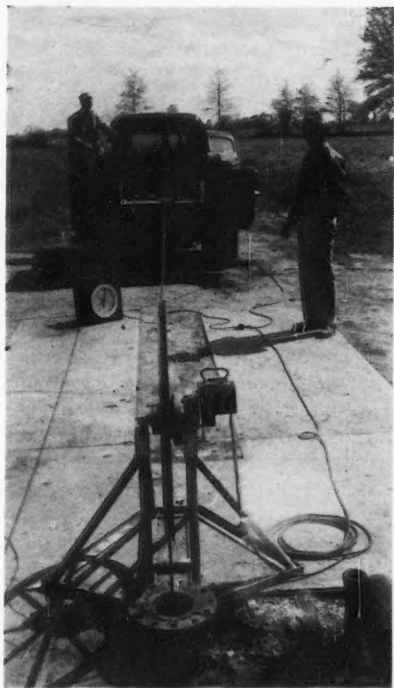


Figure 3—Two views of cable truck, measuring wheel at well head and Brown potentiometer.



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talic contact with the pipe. Rotating wheels with sharp points were tried but they were found to be unsatisfactory in heavily scaled pipes. The best contacts found so far are sharp silicon-carbide knife edges, pressed against the casing with as much force as possible, the limit being the friction which would prevent a heavily weighted probe from sliding down the casing. Even then, much shaking of the cable was necessary in some wells to obtain reproducible readings at each point. It was then noticed that the IR drop curve on the down trip might differ as much as 20 microvolts from the curve on the up trip, but both curves would have similar shapes. It was also noticed that if the probe remained in one location there was a slow change in the reading, the direction of the change being such that the up and down values tended to approach each other. It was thought that if the up and down readings could be made to agree by adjusting the pressure on the blades that the resulting readings would be correct. However, a little consideration shows that the friction on the two blades may differ by a constant amount so that

there would always be a constant thermal emf in the probe circuit, provided the speed is constant and the time interval between readings is constant.

TABLE II
Overall Drops for $I = 1$ Ampere

WELL.....	A	C	D
Anode distance from Well (Feet).....	Unknown	50	1000
Pipe resistance (ohm $\times 10^{-6}$ /ft.).....	13.3	17.75	17.75
Overall drop (mv.).....	17.0	10.73	15.3
Depth for point entrance (Feet).....	1280.0	608.0	863.0
Depth for uniform current density.....	2560.0	1216.0	1726.0
Depth of casing.....	3128.0	1489.0	1489.0
			1575.0

Use of Overall Drop to Correct Probe Measurements

The overall drop measurements provide a means for correcting the double probe measurements. It will be shown later that a simple improvement, which is being made in the probe, will eliminate this error in future measurements.

Figure 4 shows the overall IR drop measurements, made at various times on various casings, with various applied currents. The overall drop along the casing is,

$$\int_0^L I \rho dx$$

where I , the current in the casing, is an unknown function of x , and ρ is the resistance per unit length of the casing. It will be noticed in Figure 4 that whenever a series of measurements is made in which the current is changed, that the change in overall drop is very closely proportional to the change in current. This indicates that the distribution of current along the casing is fixed by the resistances in the circuit. The curves do not pass through the origin because of the galvanic currents in the casing. The overall drop changes slightly with the time, at a fixed current, but this change is not more than 10 percent in a half hour. This small percentage change is always

an increase; and it occurs because parts of the casing near the anode become polarized, which tends to force the current to enter the casing at greater depths.

Although the function $I = f(x)$ is not known, we can assume certain simple forms for it, in order to get some idea of how the current enters the casing from the earth. These results are shown in Table II. Even when the anode is only 50 feet from the well, as in Well "C," the current enters the casing at an average depth of 608 feet. These rather surprising results indicate that the anode position is of relatively minor importance and that suitable current distribution could be obtained from an anode in almost any position although more current is required when the anode is near the well. It will be shown that other considerations make it desirable to place the anode a reasonable distance from the well.

The double probe measurements made before improvement of the contact may contain rather large but probably nearly constant errors in any one run. The overall drop measurements are consistent, easily reproducible and contain negligible thermal emf errors if time is taken to permit the probe to reach thermal equilibrium. Hence, the best way to eliminate as much error as possible

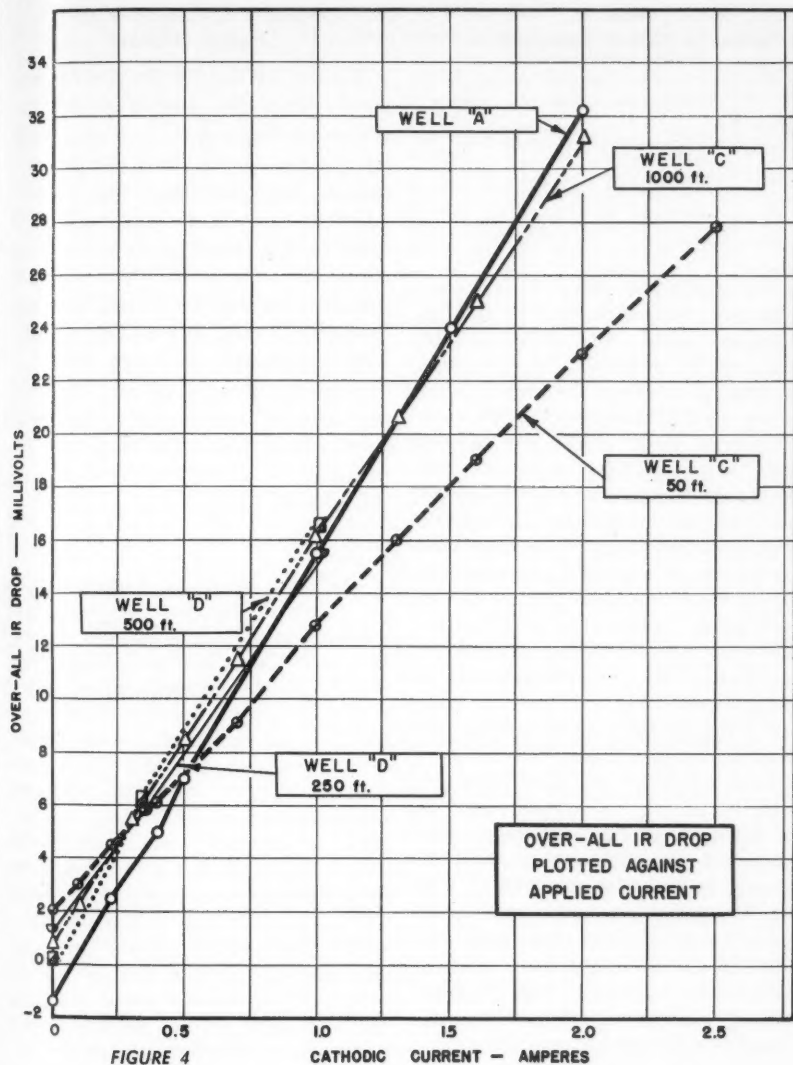


FIGURE 4

from the double probe measurements is to apply a constant correction to all the results of each run, so that the probe measurements are consistent with the overall drop

measurements. A summary of the calculated corrections, wherever such corrections are possible, is shown in Table III.

It can be seen from Table III that

TABLE III
Corrections to IR Drop Measurements With
Probes (Microvolts)

WELL	Applied Current (Amps)		Depth to Fluid (Feet)
	One	Less Than One	
A	-12 17		285
C	- 2, -1 6, 1	-2, -1	10
D	1 21, 23	3, 11	1000

the corrections for Well "C" are considerably smaller than those for the other two wells. The reason is best explained by describing the methods used to try to eliminate thermal emf errors. In low fluid level wells, copper wires were connected to the knife blades. The temperature of the blades would be affected by movement of the probe, but since the blades were in intimate contact with the casing, it was thought that the copper-steel juncture should be at the blades, because they would probably soon reach the temperature of the casing. In fluid-filled wells, it seemed preferable to attach the copper wires to the end of the spring away from the blades. The amount of heat which would flow from the knife blade to the opposite end of the spring would be negligible when the entire assembly was in fluid. It is now believed that thermal emf effects could have been greatly reduced by attaching steel wires of equal length to single knife blades, and placing both steel-copper junctures in a constant temperature enclosure on the probe assembly.

If a double probe could be designed, which would make positive contacts with the casing only when the probe is stopped, it would also probably eliminate most thermal emf errors.

Results Obtained with Double Probes

Results of the IR drop measurements with the double probe are shown in Figures 5, 6, 7 and 9. In all of these curves there is a characteristic behavior near the surface which is believed to be caused by a difference in temperature of the two contacts on the probe. It is possible that the current interchange between casing and flow line is also a contributing cause. In case further measurements are made, constant temperature copper-steel junctures should be used, and it then may be possible to determine the cause of the surface effect.

Well A

The data shown in Figure 5 was on a producing well from which tubing and rods had been removed. Because it was desirable to get the well back into production, a nearby flow line from another well was used as an anode, and only two satisfactory runs were made. Hence, the position of the anode is indefinite but measurement of IR drops on the flow line indicated that most of the current entered the earth from the flow line at a considerable distance from the well. The tubing was entirely free of corrosion, and was covered with a thin film of oil. It was easy to obtain good contact, and although this was the first measurement, it is believed that the results are accurate in showing gross anodic and cathodic areas as they actually exist on the casing. Except for the surface 100 feet, a current of 1 ampere removed all gross anodic areas to a depth of 1900 feet.

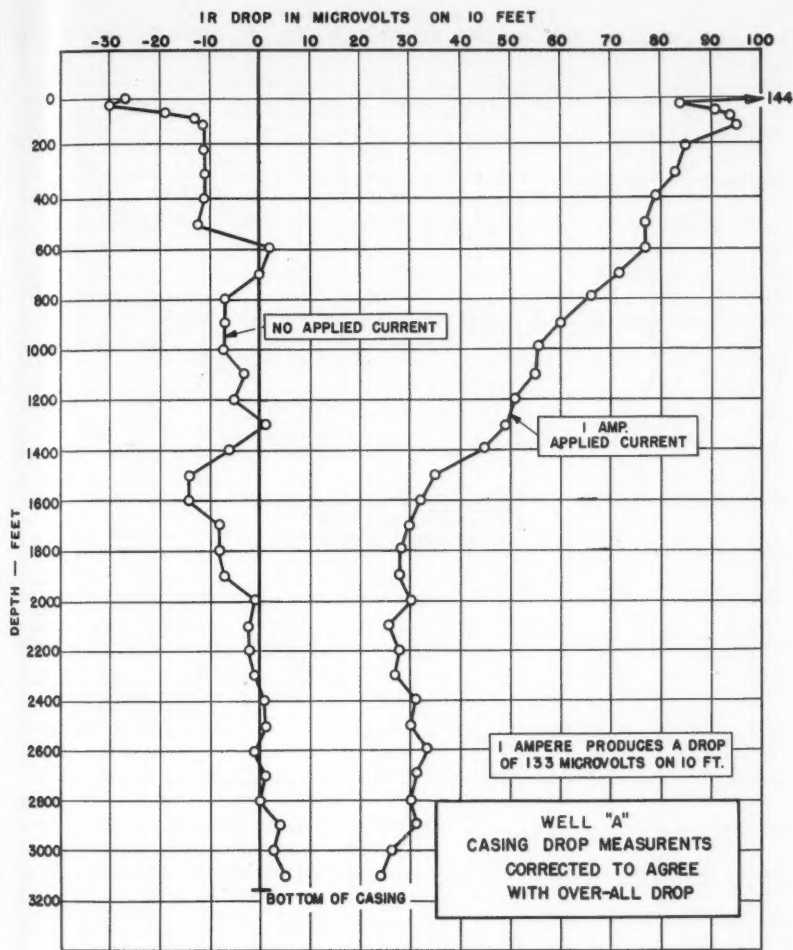


FIGURE 5

Well B

The data of Figure 6 is rather unsatisfactory for several reasons. Very hard scale in the casing made proper contact difficult. The possibility of large thermal errors was first noticed on this well but no overall drops were measured. The applied current

seems to increase both anodic and cathodic areas, rather than remove the anodic areas. These fluctuations with depth had been noticed in previous measurements and the only logical explanation of them is a mixture of joints of casing of different resistances. However, the ca-

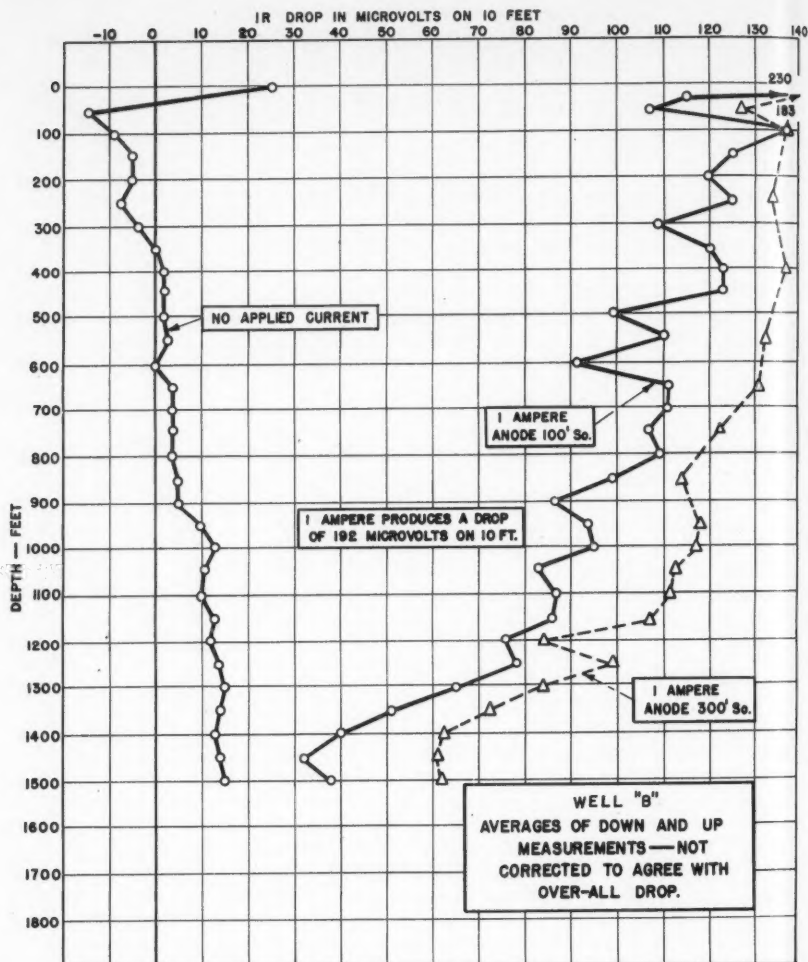


FIGURE 6

thodic curve of Figure 6 is almost identical in shape with an anodic curve obtained a year previous and so indicates that the curves are stable and characteristic of the well, and are determined principally by ohmic resistances rather than polar-

ization effects. The open circuit potential of this well is -0.99 volt with respect to calomel, which is more negative (active or anodic) than any other well by 0.13 volt. (See Table I). There was no great difference in the distribution of current from an

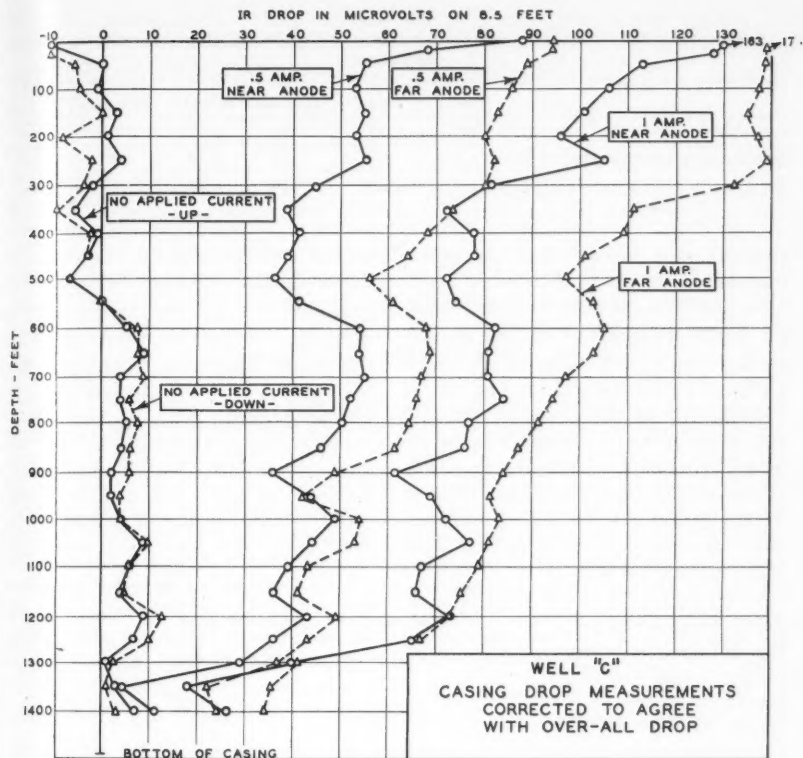


FIGURE 7

anode 100 feet and 300 feet from the well.

Well C

Since the data of Figure 6 showed that the current distribution on the casing was not sensitive to the anode position, it was decided to use the maximum possible difference in anode positions. The results shown in Figure 7 are for an installed anode only 50 feet from the well, and for an abandoned casing 1000 feet from the well. One might expect that the

small anode only 50 feet from the wellhead would give a very uneven current distribution on the casing, while the casing 1000 feet distant might be expected to give the most uniform possible current distribution, since it passes through all formations and is the same size as the protected casing. As noted previously, the thermal corrections on these measurements were practically negligible. The similarity in the shape of all the curves, and the agreement of the two zero current curves all

TABLE IV
Current Flow Between Casing and Earth Calculated from Probe Measurements on Well C (Amperes)

	Down	Up	Near Anode	Far Anode	Near Anode	Far Anode
Applied Current.....	0.0	0.0	0.5	0.5	1.00	1.00
Anodic Current.....	-0.31	-0.36	-0.345	-0.24	-0.38	-0.10
Cathodic Current.....	0.39	0.49	0.855	0.704	1.29	1.02
Sum of Current.....	0.08	0.13	0.510	0.564	0.91	0.92

indicate that the IR drop measurements are reliable to about ± 2 microvolts. The current from the nearby anode enters the casing mostly at the top and bottom of the well and is decidedly less effective in suppressing anodic areas in the central part of the casing. It is of interest to try to determine just how effective the two values of current from the two anodes are in suppressing the gross anodic areas. This can be done by subtracting adjacent probe measurements, the differences being proportional to the current flow to or from the earth between the points of measurement. The sums of these differences in terms of current are shown in Table IV.

If it is assumed that the entire circuit acts as simple ohmic resistances as is indicated by the curves of Figure 4, it follows that for any anode position the change in IR drop at any point in the casing, is propor-

tional to the applied current. The differences shown in Table IV are proportional to the differences in abscissa of the extremities of the curves of Figure 7. When the data of Table IV are plotted (Figure 8), the effectiveness of the two anodes in reducing the anodic current can be seen more clearly. Apparently current applied through the near anode slightly increases the total corrosion, but this is because the

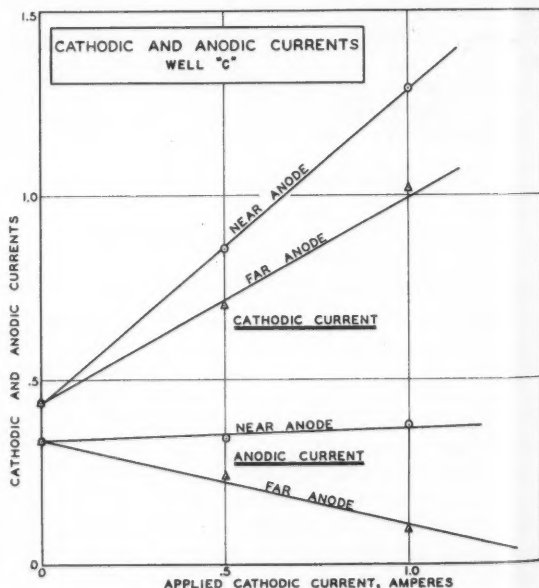


FIGURE 8

effect of variations in casing resistance has been neglected. A little consideration will show that variations in casing resistance will increase the slopes of all the curves of Figure 8 by the same amount. The figure indicates that all gross anodic areas will be removed by the remote anode when the applied current is about 1.5 amperes and that the near anode is less effective than the far anode.

Well D

Results described indicate that there is a limit as to how near the anode can approach the well. It was decided to make a similar test on another well where an installed surface anode 250 feet from the well could be compared with a well casing which was 500 feet from the well under test. Resulting IR drop measurements are shown in Figure 9. The galvanic current or open circuit curve on this well is very similar to that of Well C, the anodic areas occurring at about the same depths and having about the same intensities. Thermal emf corrections were somewhat larger because the fluid level in this well was much lower. The calculated anodic and cathodic currents shown in Figure 10 do not lie near straight lines as in Figure 8, and curves of Figure 9 show numerous small inconsistencies. For these reasons it is believed that there are larger errors in the data of Well D, which make it difficult to determine the current required to remove the gross anodic areas. However, the general appearance of the curves of Figures 9 and 10 indicates that there is very little difference in the two anode positions, so it appears that little would be gained

by placing a permanent anode farther than 250 feet from the well it is to protect.

Significance of Double Probe Measurements

In all casing IR drop measurements described, the interval between measurements has been 50 feet. The results then show whether the 50-foot length of casing is acting as a gross cathode or anode. On any such large area there are likely to be both cathodes and anodes under any condition of moderate total current flow between pipe and earth, and hence, the smaller the interval between measurements, the larger the observed current densities are likely to be. This is shown in Table V by measurements made on a well in another field where the interval between measurements was 10 feet and the probe separation was 8.5 feet. As the interval between measurements is decreased, the total circulating current appears to increase and so the current required for protection would also appear to increase. As the interval between measurements is decreased below 10 feet the apparent circulating current would probably show no further increase, not because smaller galvanic couples are absent, but because the limit of resolution of the

TABLE V
Relation of Observed Current Flow Between Casing and Earth to the Interval Between IR Drop Measurements (Amperes)

	Interval Between Measurements (Ft.)					
	10	20	30	40	50	100
Anodic Current...	2.03	1.18	1.05	0.78	0.60	0.43
Cathodic Current...	2.29	1.46	1.30	1.06	0.85	0.74

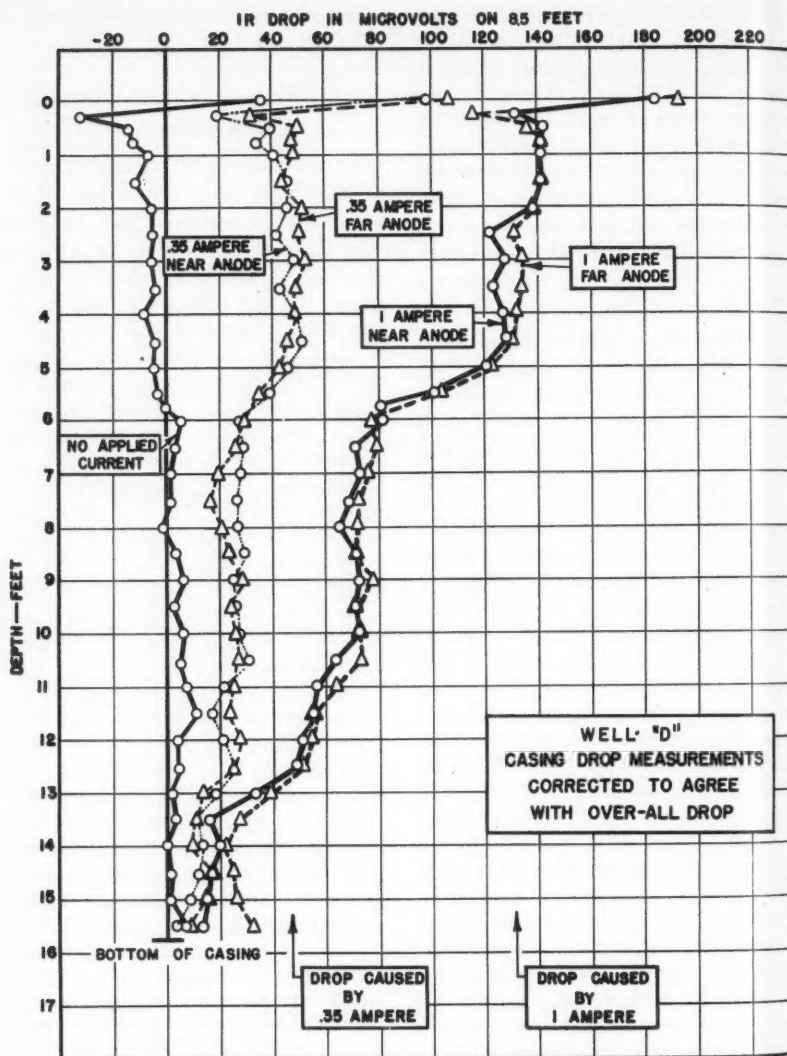


FIGURE 9

8.5-foot separation is being approached. A shorter interval between measurements will give more reliable information than the 50-foot separation, and a continuous record of the drop across 8.5 feet would give the most reliable picture possible. But even this procedure would not reveal the very small galvanic couples or determine when every part of the casing is made cathodic with the applied current.

The double probe measurements give certain important information obtainable in no other way, such as the initial gross galvanic conditions and the relative effectiveness of anodes in various positions. The fact demonstrated by Figure 8, that current from an anode too close to a structure does little good, has never been shown to the knowledge of the writers. Unless some other means is discovered for analyzing the data, double probe measurements may show that the casing is not adequately protected, but they do not provide a sure means for determining when the casing is protected.

Current-Potential Curves

The current-potential curve was shown by the senior author in 1940¹ to be a satisfactory means for determining the current required for protec-

tion. This laboratory method was tried on pipelines and gave reliable results, provided sufficient care was taken in making the measurements.² The so-called null-circuit which eliminates practically all the tedious calculations was devised by Pearson³ and has since been applied in numerous cases by Pearson and others.⁴ The Pearson circuit can be adapted for use on well casings.

The characteristics of the calomel reference electrode have been examined and found to be reproducible under field conditions, in contact with the soil. The reference electrode cannot be moved along the casing but it can be moved about on the earth's surface. In doing this it was found that more than about 75 feet from the casing the readings

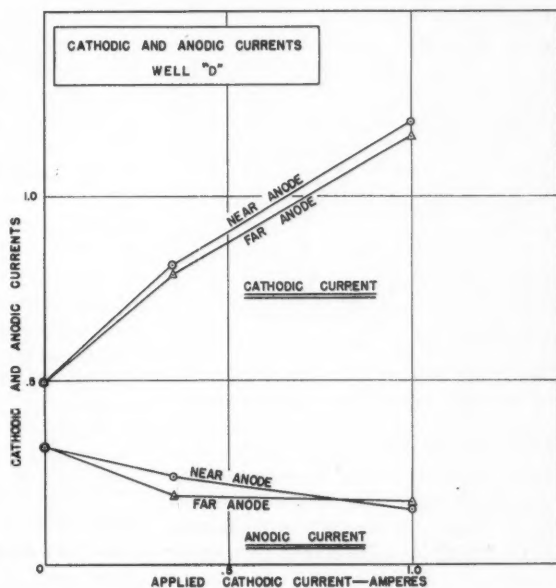


FIGURE 10

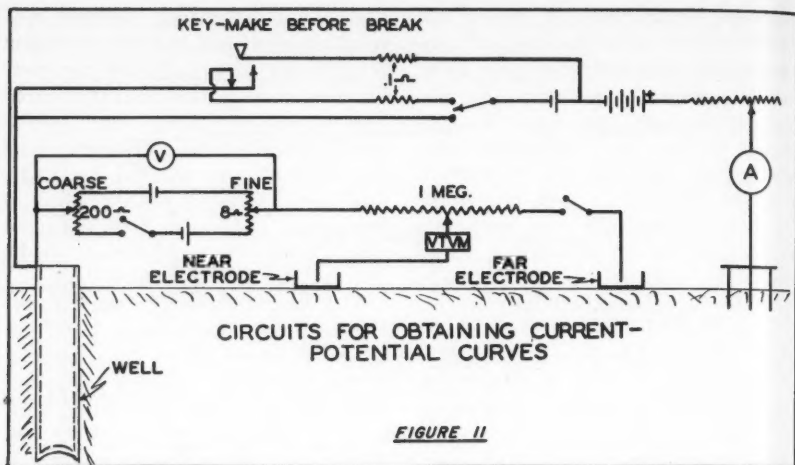


FIGURE 11

are all essentially the same, no matter how remote the electrode, unless some other large buried metallic structure is approached. This indicates that the electrode has been moved outside the field of the circulating currents on the casing, and if other IR drops through the earth are avoided, a measurement has been made which is believed to be characteristic of the surface of the casing.

Now it is desired to draw current from the casing to a buried anode and measure its potential, and at the same time keep the reference electrode "remote" from the casing. But when this current is applied with some other structure as the anode, there will be IR drops between the electrode and casing. If the true potential of the casing is to be measured, these IR drops through the earth must be eliminated from the results.

The schematic circuits shown in Figure 11 were used to obtain true

current-potential curves of the external surface of the casing. The anode was either temporary, consisting of several 5-foot lengths of 2-inch pipe, or an abandoned well. The measuring circuit is a modified Wheatstone bridge described by Pearson,³ in which two arms are the earth and the other two arms are the megohm resistor. The calomel electrodes were placed with the following objects in mind: The measuring electrode should be as far from the well as possible so that deeper parts of the casing will have some effect on it; the far electrode should be placed closer to the anode so that there is sufficient voltage between the electrodes to balance the bridge.

Following is the procedure for operating the circuits: With S_1 open, and with the anode circuit also open, the open circuit potential of the well is determined by adjusting the potentiometers connected to voltmeter V until the vacuum-tube

voltmeter indicates zero. The voltmeter V then reads the open circuit potential of the well.

With a small current through the ammeter A, and with S_1 and S_2 closed, the contact on the one megohm resistor is adjusted until depressing the key in the anode circuit produces no change in the VTVM deflection. This adjusts the circuit so that the IR drop between the near electrode and the well is equal to the drop between the contact and the well through part of the megohm resistor. The double potentiometer is then adjusted until the vacuum-tube voltmeter indicates zero. The potential of the well casing is then read on voltmeter V.

Potential readings are made in this manner with gradually increasing currents in the anode circuit, and with uniform time intervals of about three minutes between readings.

Current-potential curves were obtained on three wells using the null circuit with the anode and measuring electrode in various positions. These curves are shown in Figure 12. Similar curves were also obtained by correcting the measured potential for the IR drop between electrode and casing (Curves 1 and 2). A similar curve was also obtained by opening the anode circuit and quickly measuring the potential (Curve 8). It will be noticed that each of these curves consists of two parts, a nearly straight, horizontal part and another nearly straight line with a steeper slope. The intersection of these two straight lines is the value of the current which is just sufficient to protect the well from corrosion.

The reason for this is explained elsewhere.^{1, 3} The method has the fault that the measurements are difficult to make and require considerable time. In the opinion of the writers the basis of this method is fundamentally sound and more reliable than the methods that are usually used on pipelines when it is assumed that a potential of -0.85 volt with respect to a calomel or copper-sulfate electrode will protect the pipe. It should be pointed out that the Well C has a potential of about -0.87 volt and Well B, -0.98 volt, so according to pipeline methods, they should be protected without any applied current, yet both of these well casings have holes in them. It is thus seen that the usual pipeline methods for determining current requirements are not applicable to the well casings in this field. The curves of Figure 12 all show that a current of about 1 to $1\frac{1}{2}$ amperes will adequately protect that part of the casing whose potential is being observed with this arrangement. At the present stage we have no means for judging how much of the casing is being "observed."

One might think that since the current scale in Figure 12 is being compressed for larger values of current, that a small unbalanced resistance between calomel electrode and casing would cause the curves to increase in slope toward the right, and so the straight and sloping part of the curves may be caused by errors in adjusting the measuring circuit. But Curve 8 is a true open circuit measurement. Curve 9 is a calculated curve, with an assumed unbalanced resistance of 0.01 ohm between calomel electrode and cas-

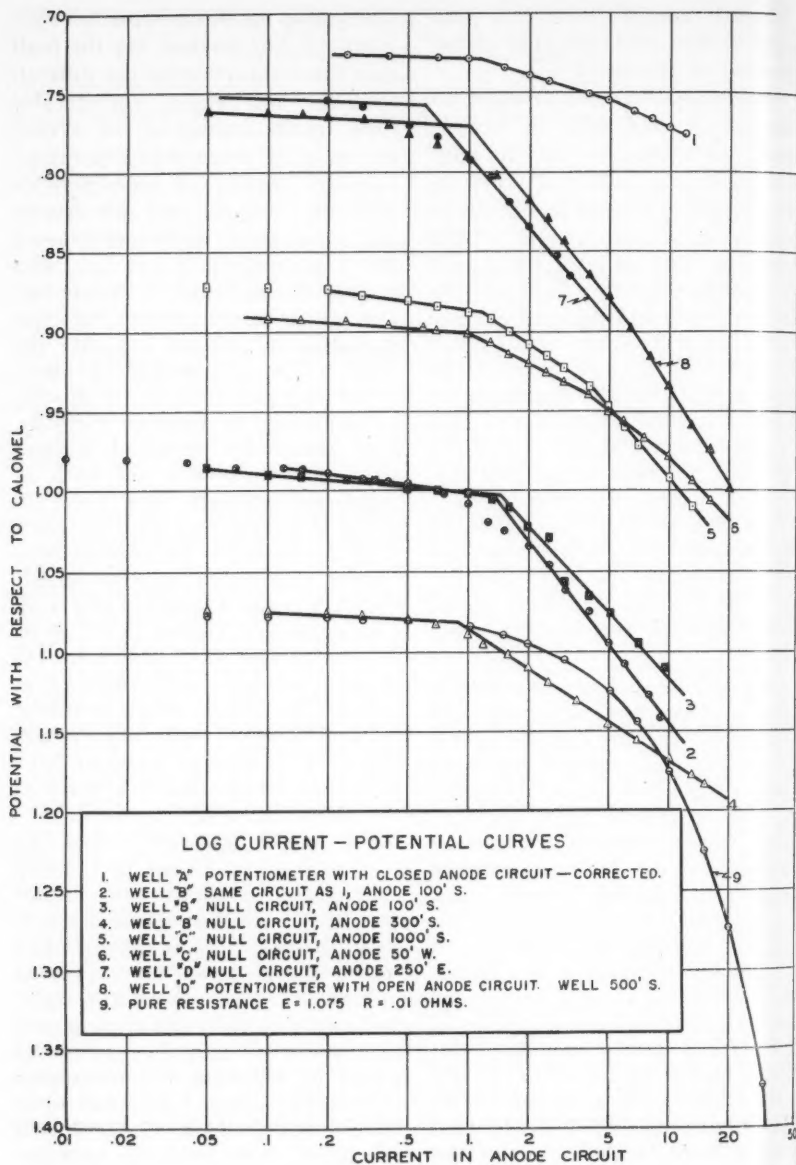


FIGURE 12

ing. It will be noted that the true resistance curve is decidedly different from any of the actual curves, so the actual curves are not the result of this kind of error of measurement.

Discussion and Conclusions

Current Requirements for Protection

Two methods have been used to determine the amount of current required to protect a well casing. Both of these methods have certain limitations and faults. The casing IR drop measurements will reveal the presence of gross anodic areas, and the method assumes that when gross anodic areas are removed, all anodic areas are removed. When one attempts to use the method to reveal smaller anodic areas, it is not certain whether the apparent anodes are real, or are the result of errors of measurement and variations in casing resistance.

The log current-potential curves have the fault that the measured potential may not be true potential of the well with respect to a reference electrode in remote earth, because the upper part of the casing will have the greatest effect on the measured potential.

The results with either method are as closely reproducible as could be expected, and they both give a value of about $1\frac{1}{2}$ amperes as the required protective current. When the results agree, within the precision of the separate methods, the only sensible conclusion is that they are both right.

Current Distribution on Casings

The data on IR drop measurements, with anodes in various positions are sufficiently reliable to

determine the current density along the casing, and the results show, even with short time measurements that it is easy to obtain satisfactory current distribution along the casing. The top and the bottom of the casing seem to collect most of the current, and the central part of the casing seems to be the most difficult to protect. However, this may be because of the four wells tested the extremities of the casing are more subject to corrosion because they are in formations of low resistivity.

Comparison of Well Casings with Pipelines

Behavior of well casings so far examined differs radically from the behavior of uncoated pipelines under cathodic protection. It appears that a 6-inch OD well casing, 1500 feet long can be adequately protected with about 1.5 amperes, which is equivalent to a current density of 0.65 milliamperes per square foot. This is lower than the requirements of surface pipelines, which are reported to require from 1 to 15 milliamperes per square foot.⁵ One would naturally expect lower current requirements on well casings because the oxygen supply is either very low or zero, and most of the casing is covered with cement. However, little is known about the mechanism by which a continuous corrosion rate is maintained when the casing is insulated from the flow line, nor is it possible to tell exactly from these short time tests what to expect from permanent installations.

Suggestions for Cathodic Protection of Well Casings

All of the measurements reported

here were made in a relatively short time. Nothing is known about the changes in potential or current distribution along the casing with continuously applied protective current. Potential measurements over a long time should be obtained in order to make more reliable estimates of current requirements. This information could best be obtained with permanent cathodic protection installations on several of the wells. Because of the large number of nearly identical units required, and because well casings differ somewhat from pipelines, it is desirable to work out a uniform design for the installation.

In making a test of cathodic protection the following considerations should fix the location of each anode at Loudon: 1) it must be at least 200 feet from the well; 2) it should be located in a low place and buried where the soil is not likely to dry out; 3) it should be removed as far as possible from the flow line and from other pipelines; 4) it is preferable to locate it in soil of low resistivity. With some wells it may be impossible to locate the anode so that it does not expose any of the surface pipes to electrolysis. All questionable pipelines should be tested for stray currents, and all anodic conditions corrected before the rectifier is turned on.

The following seems to be the best procedure for controlling the

external corrosion of well casings. Measurements should be made to determine the magnitude of the galvanic current between flow lines and casings, and if these currents are found to be of appreciable magnitude with the casings anodic, it would be advisable to insulate the flow lines from the casings. It is obviously cheaper to reduce the current flow from the casing with insulation than with cathodic protection. That is, it is cheaper to install insulation early in the life of the field rather than wait until leaks appear and then try to stop all the corrosion with both insulation and cathodic protection. It is not considered advisable to insulate only a part of the wells in a field. Wells that originally showed small currents would probably carry larger currents after other wells are insulated. Partial insulation might not reduce the total current flow and it might produce worse anodic conditions on surface structures. The production records of individual wells may be of value in locating leaking casings. Sudden changes in water production or wide differences between adjacent wells might indicate leaks from sands above the producing sands. It is not considered desirable to apply cathodic protection to a well casing unless corrosion leaks have been discovered and economic considerations indicate some saving can be effected by its use.

References

1. S. P. Ewing, Determination of Current Required for Cathodic Protection, Proc. AGA, 613 (1940).
2. McRaven & Ewing, Unpublished data.
3. J. M. Pearson, Null Methods Applied to Corrosion Measurements, Trans. Electrochem. Soc., 81, 485-510 (1942).
4. Logan, Pearson, Hadley, Denison & Smith, Determination of Current Required for Cathodic Protection, Pet. Engr., 14, No. 10 (1943) July.
5. K. H. Logan, Underground Corrosion, Bureau of Standards Circular C-450 (1945).

Effect of Atmospheric Corrosion on Maintenance and Economics of Overhead Line Hardware and Guy Strand* -Part 3

(Conclusion)

By C. J. Couy*

Zinc Coated Steel Guy Strand Maintenance Replacement

BECAUSE of the almost infinite possible number of combinations of load to be supported and its own physical position in space, practically each guy strand installation constitutes an individual replacement problem. Also, this replacement must be made in time, or often risk serious structural failure. Guy strand maintenance should, therefore, be given particular attention.

Collection of Data

The uniform, quasi-circular cross section of strand suggests the amenability of its replacement problem to the method developed in the last section for units of uniform section.

So it was decided to collect a sufficient number of specimens of each of the sizes of strand in use on the system, of as uniform as possible age distribution of four years and over, and of representative geographical dispersion over the industrial, urban

and rural areas of the district; then attempt to determine:

1. Rates of diameter decay for areas of various pollution severity.
2. Relation of strength and corroded diameter.

With such information available it would only be necessary to also know the maximum load involved, including the required safety factor, to achieve intelligent replacement.

Unfortunately, not as many specimens as desirable could be collected because of the number of qualifications to be met by each, positive identification of installation date being the most difficult, especially for older specimens.

Tabulation and Analysis of Data and Test Results

In Table VI are given the data and test results from 42 specimens of 5/16-inch steel strand. Each specimen was mechanically cleaned and weighed; length, minimum and average diameters measured; the condition of the coating and the type of corrosive attack on the steel recorded. The specimen was then

* A paper presented at the Annual Meeting of NACE in Chicago, Ill., April 7-10, 1947.

* Duquesne Light Co., Pittsburgh, Pa.

TABLE VI
Corrosion Data—Overhead Line Hardware

Kind: 5/16 Inch, Class A Zinc Coated, Steel Guy Strand

Original Ultimate Strength Rated 6000 Lbs.
Minimum Allowable: Various

Weight—New 0.220 Lbs./Ft.
Original Principal Dimensions 0.316-Inch (3 x 0.109)

Specimen Number	Kind of Corrosion Area	Year of Installation	Age (Years)	Galvanizing or Other Coating	Primary Kind of Corrosion	Physical Condition at Removal						Original				Remarks
						Specimen Length (Feet)	Minimum Diameter (Inch)	Average Diameter (Inch)	Weight (Lbs.)	Percent Original Weight	Percent Original Critical Dimension (Day/Do)	Breaking Strength (Lbs.)	Percent Original Breaking Strength	Percent Elongation	Percent Elongation	
1	H ³	1920	23	4	U	5.72	0.225	0.230	0.627	49.9	72.8	1325	20.1	0.8	8.0x	5.25x
2	L ^{3H}	1920	23	4	U	5.44	0.261	0.276	0.758	63.3	87.3	1830	27.7	1.1	11.5x	9.50x
3	L ²	1922	21	4	P	6.19	0.308x	0.313	1.031	75.5	99.1	2000	30.3	2.0	20.0	10.00
4	H ²	1924	19	4	L	5.80	0.211	0.248	0.922	72.2	78.5	765	11.5	1.1	14.7	7.50
5	H ²	1925	18	4	L	6.24	0.237	0.271	1.148	83.6	85.7	1945	30.8	0.55	4.4	6300
6	L ³	1925	18	4	U	6.16	0.263	0.273	1.043	77.0	86.4	4075	66.7	2.7	18.0	6115
7	L ³	1925	18	4	U	6.31	0.274	0.282	1.086	78.2	89.2	4685	76.7	6.1	40.7	6115
8	L ³	1925	18	4	L	6.33	0.257	0.285	1.266	90.8	90.2	3680	57.0	0.8	8.6	6460
9	H ³	1925	18	4	U	6.30	0.214	0.229	0.744	53.7	72.5	1875	30.7	0.92	6.1	6115
10	L ³	1925	18	4	P	5.04	0.298	0.300	0.969	87.4	95.0	5370	86.2	9.5	100.0	6230
11	L ²	1925	18	4	P	6.21	0.263	0.276	1.000	73.2	87.4	5100	61.0	0.92	14.2	7720
12	H ²	1926	17	4	U	6.21	0.244	0.256	0.923	67.6	81.0	5885	x	2.2	x	5550
13	L ²	1926	17	4	U	6.31	0.273	0.275	1.227	88.4	87.1	9380	100.x	5.5	100.x	8030
14	H ²	1926	17	4	P	6.00	0.260	0.263	0.875	66.3	83.2	6275	78.7	3.1	48.7	7970
15	H ³	1927	16	4	U	6.01	0.228	0.238	.....	x	75.2	2385	33.3	1.25	13.2	7150
16	H ³	1927	16	4	P	5.81	0.282	0.285	1.006	76.5	90.2	4065	66.4	1.3	18.6	9135
17	H ³	1927	16	4	P	5.81	0.282	0.285	1.006	76.5	90.2	4065	66.4	1.3	18.6	9135
18	H ³	1927	16	4	P	5.81	0.282	0.285	1.006	76.5	90.2	4065	66.4	1.3	18.6	9135

Core strand rusted and slightly pitted, 1 strand completely gone.

Core strand slightly rusty.

Severe pitting entire length. Strands loose. Core strand corroded.

Severe local corrosion at serve.

Severe local corrosion at serve.

Local corrosion at serve.

Specimen from across Railroad tracks.

Core strand rusty and pitted.

Slight pitting.

Telephone cable messenger. Local corrosion at flange.

[illegible]

(a) H—Severe corrosion area. L—Average corrosion area. Exponents 2 or 3 indicate degree of agreement of the three parameters, average diameter, unit weight and breaking strength, from graphs of Figs. 27, 28 and 30.
 (b) 1—Zinc coating still entire. 2—Zinc coating perforated but still effective. 3—Zinc coating partially present but no protective value. 4—Zinc coating completely gone.
 (c) U—Uniform wear, no apparent pitting. P—Fitted uniformly. L—Severe localized attack.
 (d) Core strand data. x—Values marked x are incorrect or doubtful; not used on graphs.

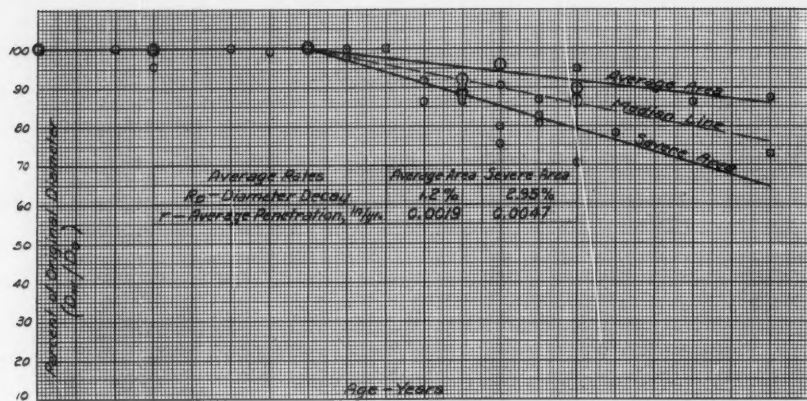


Figure 16—Average diameter-Age relation for 5/16-inch class A-coated, galvanized guy strand.

slowly loaded to failure and its ultimate strength and percent elongation determined. A piece of the core-strand, previously cut off from each specimen, was also loaded to failure, its ultimate strength being used to calculate that of the strand when new and its percent elongation being considered that of the strand when new.

All data and test results, as recorded in Table VI, are self-explanatory with the assistance of the notes following the tabulation. These results are plotted in Figures 16 to 21, inclusive, resulting in fairly definite trend graphs.

The segregation of pollution areas, attempted by the use of median

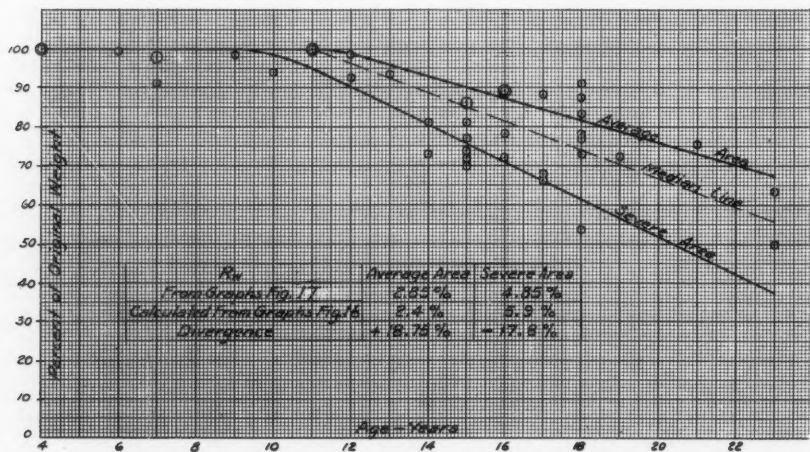


Figure 17—Unit weight-Age relation for 5/16-inch class A-coated, galvanized guy strand.

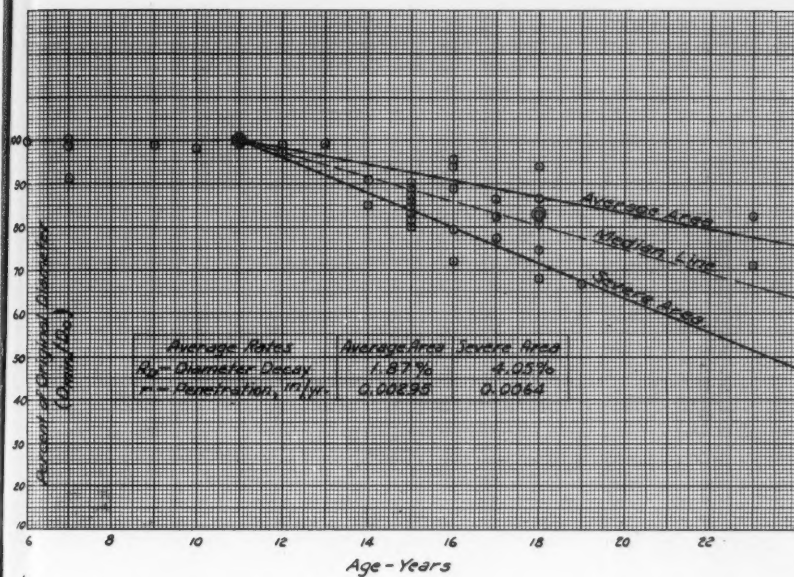


Figure 18—Minimum diameter-Age relation for 5/16-inch class A-coated, galvanized guy strand.

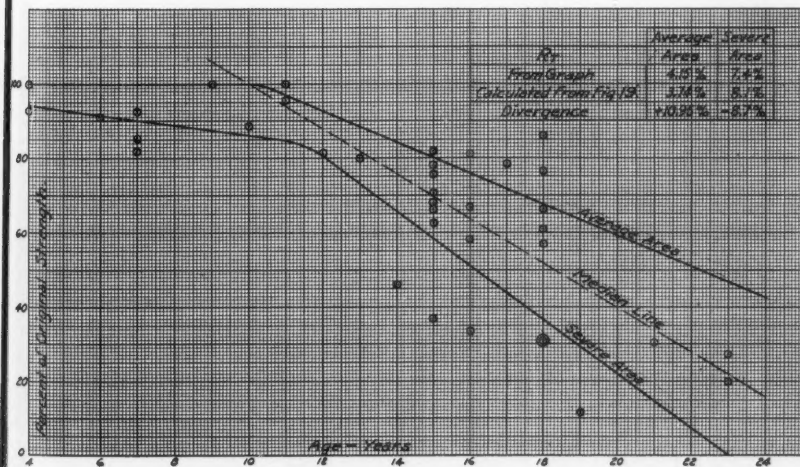


Figure 19—Strength-Age relation for 5/16-inch class A-coated, galvanized guy strand.

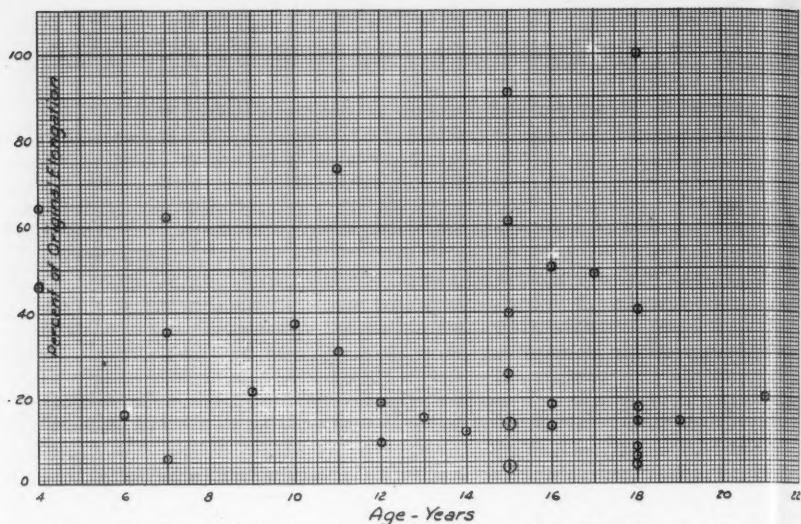


Figure 20—Ductility-Age relation for 5/16-inch class A-coated, galvanized guy strand.

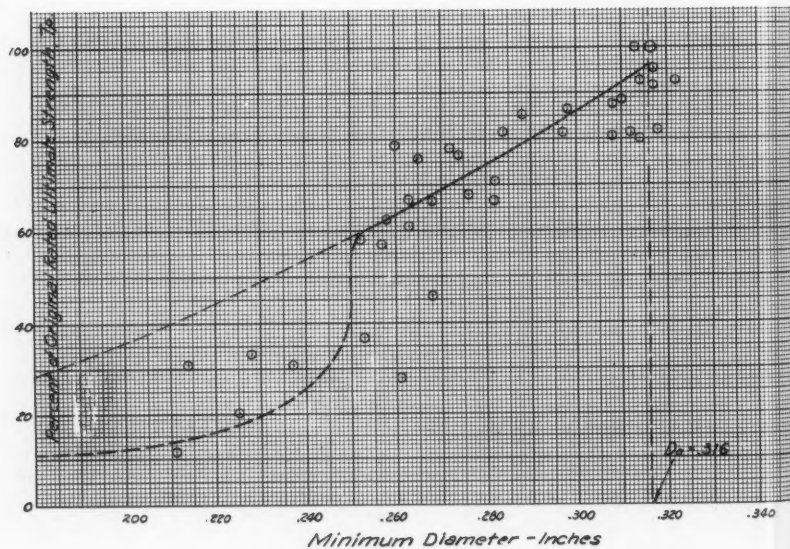


Figure 21—Corroded strand strength of 5/16-inch galvanized guy wire.

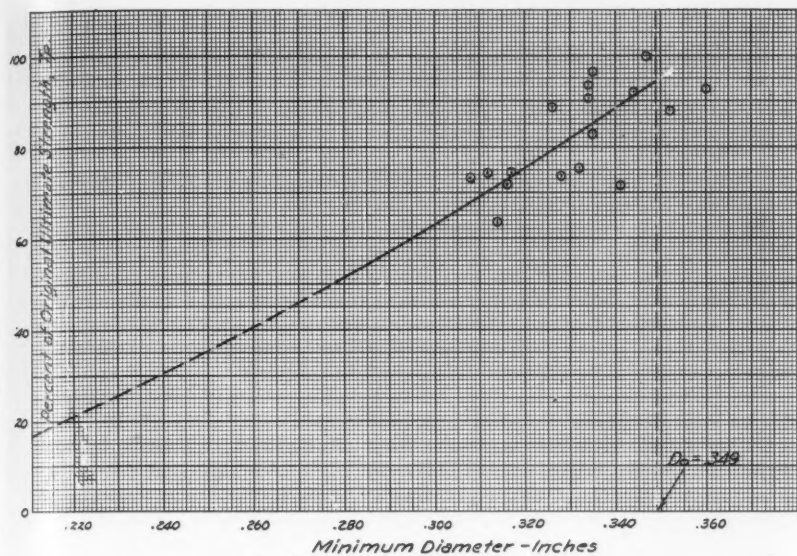


Figure 22—Corroded strand strength of 3/8-inch galvanized guy strand.

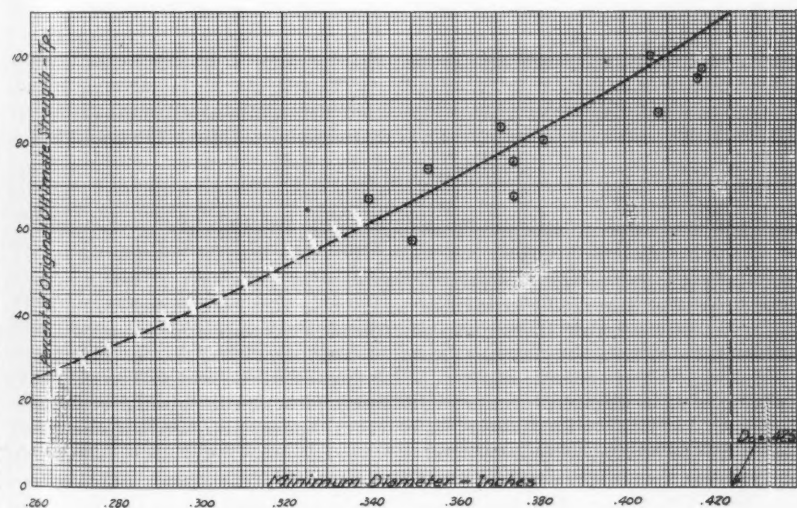


Figure 23—Corroded strand strength of 7/16-inch galvanized guy wire.

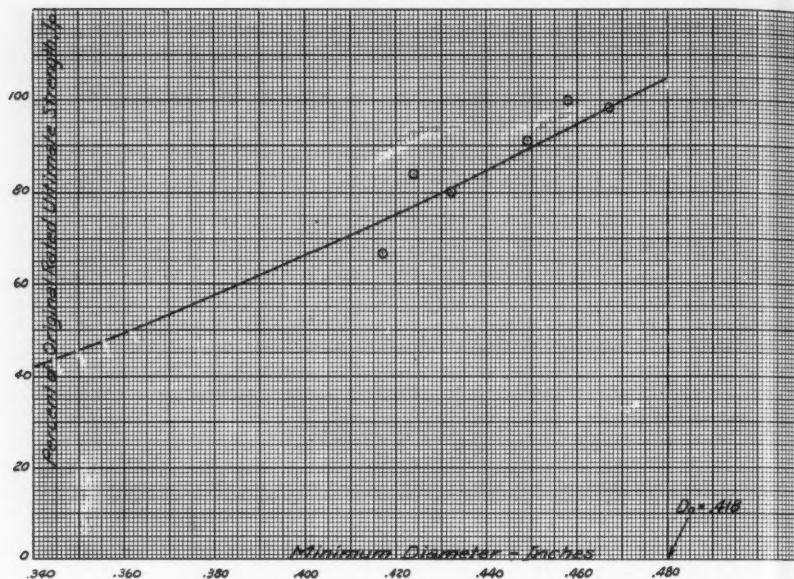


Figure 24—Corroded strand strength of 1/2-inch galvanized Seimens-Martin messenger cable.

lines on Figures 16, 17 and 19, and observation of the degree of agreement, as recorded in column 2 of Table VI, is only fair.

The only positive conclusion derived from analysis of these data as well as other available information is that the only parts of the area that can be classed consistently as of severe pollution are the lowest parts of the industrial valleys traversed by trunk line railroads; also the adjacent areas of higher elevation in the direction the prevailing winds blow the industrial fumes and flue gases.

The previously calculated two-to-one relationship of weight decay rate to that of average diameter rate, Figure 17 and Figure 16, and also

of strength decay rate to that of minimum diameter, Figure 19 and Figure 18, materialize reasonably well, particularly the latter. The percent divergence from agreement are indicated in Figures 19 and 17.

Attention is called to what has been called the "effectiveness" of the zinc coating, as indicated by the beginning of the sloping characteristic in Figures 16, 17 and 18, starting at about 11 years after installation, while the coating apparently disappears in five to eight years, as indicated in Table III. The strength-age characteristic of Figure 19 indicates appreciable drop in strength soon after installation, however, although the full decay rate does not set in until after an exposure of nine to ten years.

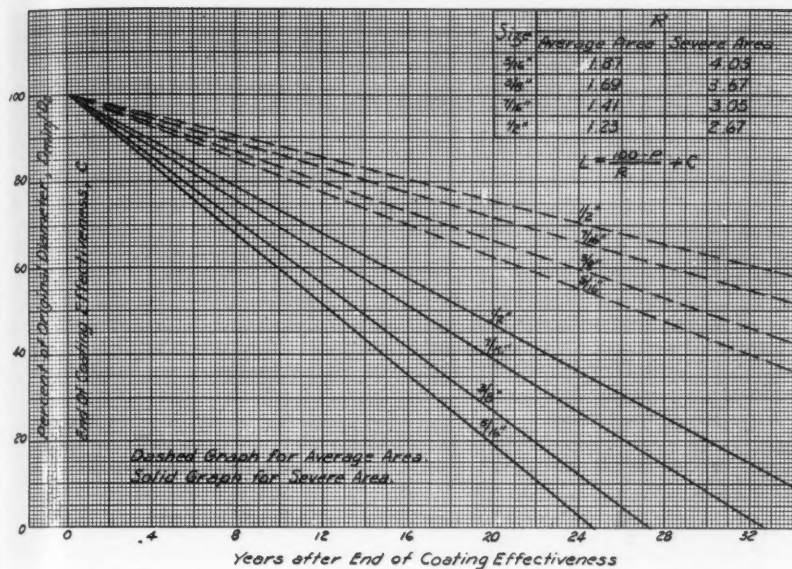


Figure 25—Remaining minimum diameter versus age for 7-strand galvanized guy strand.

It should also be noted that the plot of specimen elasticity vs. age, Figure 20, indicates no trend, being entirely random. It should be clear from this that the original elasticity of the strand cannot long be depended upon to relieve overloads, emphasizing the necessity for regular inspection and timely replacement.

The relationship of remaining strength vs. minimum corroded diameter, Figure 21, maintains a quasi-parabolic relationship of the form

$$\begin{aligned} \text{when } T_p &= k_1 d^2 + k_2 \\ &[17] \\ \text{and } k_1 &= 1000 \\ k_2 &= -4 \end{aligned}$$

This applies to approximately 60 percent of original strength, where the

relation becomes indefinite, strength dropping off rapidly.

While specimens of a sufficient age spread could not be secured for the 3/16-inch and 7/16-inch steel and the 1/2-inch Siemens Martin (now obsolete), to determine the trend of their decay rates, Figures 22, 23 and 24 are the strength-diameter relations, indicating the parabolic form, similar to that of Figure 27 for the 5/16-inch strand and probably applicable to 50 percent original strength.

There is reason to believe that the inches per year penetration of all four sizes of strand in consideration is substantially the same. On this assumption, Figure 25, indicating the maximum rate of decay of diameter for all four sizes, has been

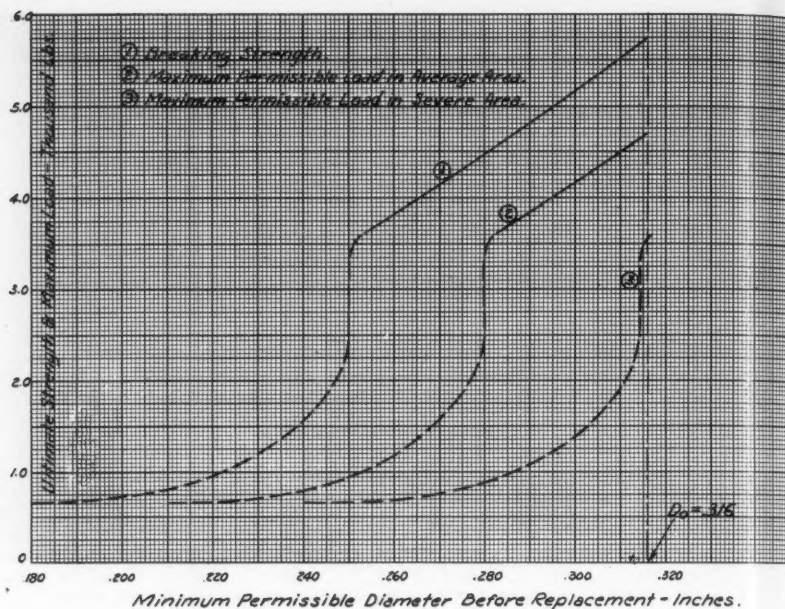


Figure 26—Diameter at replacement of 5/16-inch galvanized guy strand.

derived from that of Figure 18 for the 5/16-inch strand.

Strand Replacement Diameters

The strength vs. minimum diameter graphs of Figures 21, 22, 23 and 24 have been re-plotted in Figures 26 to 29, inclusive, to indicate for any diameter and on the basis of a five-year inspection period:

1. Breaking strength in pounds.
2. Maximum permissible load, pounds, in average pollution area.
3. Maximum permissible load, pounds, in severe pollution area.

For convenience in use, the replacement diameters for average and severe pollution areas have been tabulated for all four sizes of strand in Table VII.

In order to apply the graphs of Figures 26 to 29, or Table VII, to the replacement of strand, the maximum loading must be known. Table VIII has therefore been compiled indicating the loading imposed by, or minimum guy strength requirements for, each conductor supported. This table covers the usual conductor sizes and tensions used and angle conditions encountered in urban construction, under each of the three NESC grades of construction.

Economic Comparisons

Effect of Service Life on Annual Costs

Economical operation of a structural system is achieved: (1) by non-wasteful replacements; (2) by the use of the most economical replace-

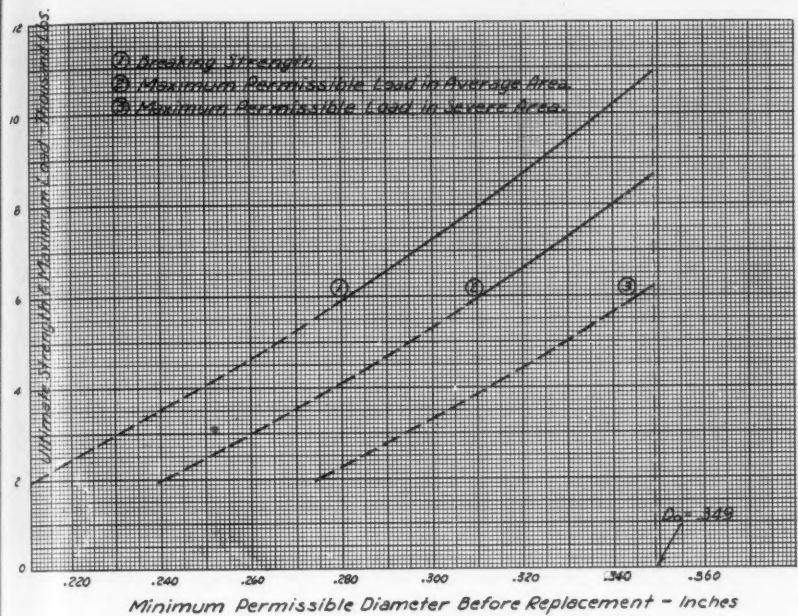


Figure 27—Diameter at replacement of 3/8-inch galvanized guy strand.

ment parts as determined by resulting lower annual costs. Brief consideration will be given the latter point in the light of probable service life.

Annual costs, the accountant's fixed charges, include such items as depreciation, interest, taxes, obsolescence, premature retirement, accidental damage, etc. Of these all but the first, being investment charges, may be usually taken as a certain fixed percentage of total plant investment.

Depreciation, however, as applied to any unit may be taken as equal to the reciprocal of service life.

Thus, in general, we may write for any unit of material:

$$y = a(1 + p) \left(1 + \frac{1}{L} \right) \quad [18]$$

where

- y = annual cost
- a = material cost (per unit)
- p = labor ratio (installation labor cost to cost of material)
- I = investment charges (not including depreciation)
- L = service life

Since p and I are same for equivalent units, economic comparisons and studies may be made by using a or L as the independent variable and solving for the other.

Maximum Permissible Price for More Durable Substitute Materials

Let: L_1 = service life of unit No. 1
x = ratio of material cost of

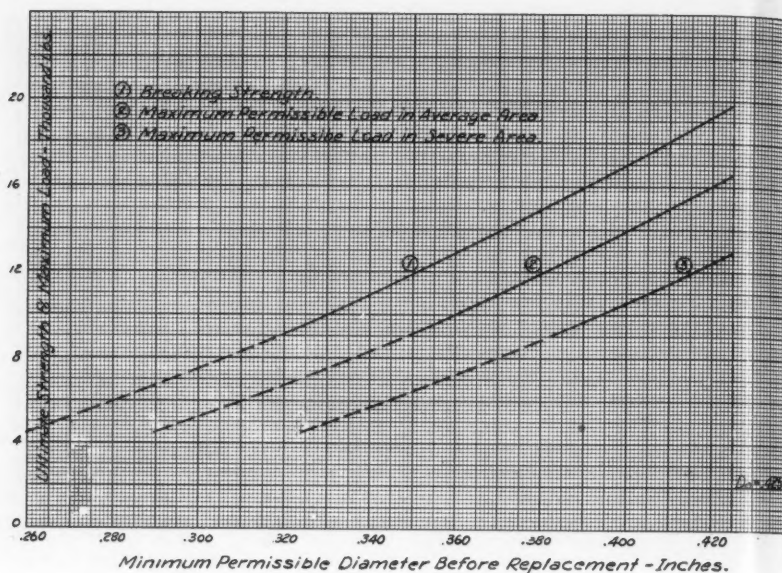


Figure 28—Diameter at replacement of 7/16-inch galvanized guy strand.

improved unit No. 2 to that of unit No. 1.

z = ratio of service life of No. 2 to that of No. 1.

Then by using equation 18 and equating the annual costs for the two units, it can be shown that,

$$x = \frac{p(z-1) + z(IL_1 + 1)}{zIL_1 + 1} \quad [19]$$

In Figure 30 is given a family of curves of equation 19, with z as the independent variable and the following constants,

$$\begin{aligned} p &= 0.5 \\ I &= 0.11 \\ L_1 &= 10, 20, 30 \text{ and } 40 \text{ years} \end{aligned}$$

Thus it is only necessary to determine L_1 , as previously discussed,

to use such solution for any condition applying.

Comparison of Annual Costs of Hot-Dip Galvanized Strand

Based on Proportionality of Installation Labor Cost to Material Cost

Utilities grade guy strand is normally available in three coating classes, A, B, and C, carrying 0.8 to 0.9, 1.6 to 1.7, and 2.4 to 2.5 ounces of zinc per square foot of surface, respectively. Zinc coatings are produced by the hot-dip and the electrodeposition methods at competitive prices.

All strand displays great variability of service life due to the variability of the loading, construction

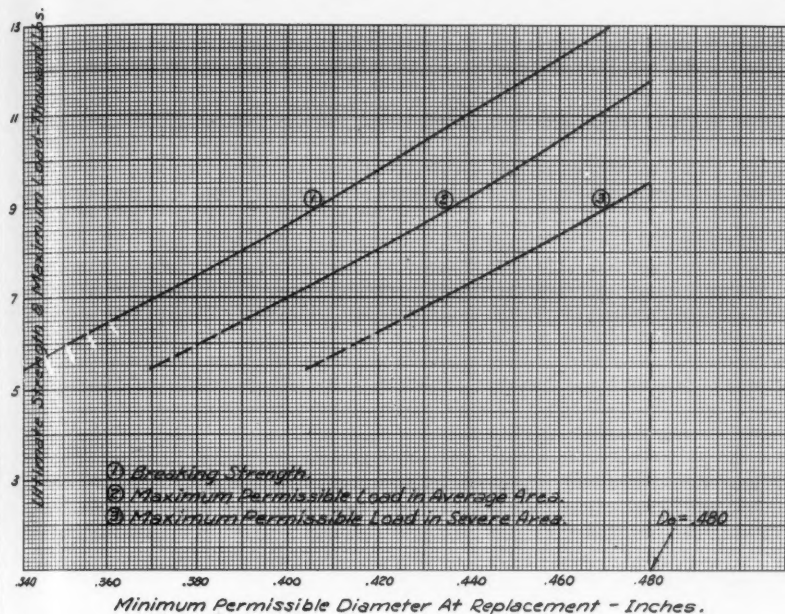


Figure 29—Diameter at replacement of 1/2-inch Siemens-Martin galvanized guy wire.

grade, and exposure combinations to which it is subject. Generally applicable cost comparisons are, therefore, usually difficult to make.

The strand service life derivations of the previous section have been used in equation 18 in the following cost comparison of the three classes of hot-dip galvanized strand.

Let the annual cost of 5/16-inch, class A coated strand be

$$y_a = a(1+p) \left(1 + \frac{1}{L_a} \right) \quad [18a]$$

Also the annual cost of any other size and/or class strand, assuming equal labor ratio for all sizes and/or classes of strand, would be

$$y_a = A(1+p) \left(1 + \frac{1}{L_a} \right) \\ = ka(1+p) \left(1 + \frac{1}{L_a} \right) \quad [18b]$$

$$\text{where } k = \frac{A}{a}$$

While equation 18b gives the annual cost for any strand at any labor ratio, a more general form, independent of labor ratio, would result in a more easily applicable expression. This may be accomplished by dividing equation 18b by the in-place cost of the 5/16-inch, class A coating strand, $a(1+p)$,

$$y_r = \frac{y_a}{a(1+p)} = k \left(1 + \frac{1}{L_a} \right) \quad [20]$$

Equation 20 may be called the relative annual cost for any strand which, obviously, multiplied by $a(1+p)$ would result in the absolute annual cost.

In Figures 31 and 32, for average and severe exposure, respectively, are plotted the graphs of equation

TABLE VII
Minimum Permissible Strand Diameter Before Replacement for Average
and Severe Areas of Pollution.
Pittsburgh, Pennsylvania

Minimum Strength Required (Lbs.)	$\frac{5}{16}$ " Strand (6000 Lb.)		$\frac{3}{8}$ " Strand (11500 Lb.)		$\frac{7}{16}$ " Strand (18000 Lb.)		$\frac{1}{2}$ " Siemens Martin (13000 Lb.)	
	Maximum Permissible Diameter (Inch)		Maximum Permissible Diameter (Inch)		Maximum Permissible Diameter (Inch)		Maximum Permissible Diameter (Inch)	
	Average	Severe	Average	Severe	Average	Severe	Average	Severe
2400	(.240)	(.274)						
3000	(.262)	(.296)						
3600	.282	.316+		(.305)				
4000	.295	....	(.278)	(.312)				
4500	.310	....	(.286)	(.321)				
5000			(.295)	(.329)				
5500			.303	.337				
6000			.311	.345	(.310)	(.345)	(.370)	(.403)
6500			.318	.349+	(.316)	(.351)	(.380)	(.415)
7000			.326	....	(.323)	(.358)	.400	.425
7500			.333	....	(.329)	(.363)	.409	.435
8000			.340	....	(.335)	(.370)	.419	.444
8500			.347	....	(.341)	(.376)	.428	.453
9000					.347	.382	.436	.462
9500					.353	.387	.444	.471
10000					.359	.393	.453	.479
10500					.364	.399	.461	....
11000					.370	.404	.469	....
11500					.375	.410	.477	....
12000					.380	.415		
12500					.385	.420		
13000					.390	.425		
13500					.395	....	
14000					.400	....	
14500					.405	....	
15000					.410	....	
15500					.415	....	
16000					.420	....	
16500					.425	....	

Values in parentheses are not usable, being below 60 percent of original ultimate strength for the $\frac{5}{16}$ inch strand, and below 50 percent of the original ultimate strength for the $\frac{3}{8}$ inch, $\frac{7}{16}$ inch and $\frac{1}{2}$ inch strands. See text.

20 for all three grades of 5/16-inch, 3/8-inch and 7/16-inch hot-dip galvanized strand. Values of k used were derived from manufacturers' quotations, prior to release of price controls. Values for L_A were secured by the use of Table VII and Figure 25 of the preceding Section, plus the life of the zinc coatings.

Correction Factors for Equal Installation Labor Costs for Equal Sizes of Strand

In utility plant cost accounting the simplest method for distributing installation labor costs for the smaller items is by apportionment in proportion to material cost, or a con-

stant labor ratio. This is the assumption made in the preceding derivation.

While there could be no objection to this method as applied to equivalent coatings of various size strand, it might be considered objectionable from sales or an engineering point of view to apply proportionately larger installation labor costs to equal size strands of heavier coating.

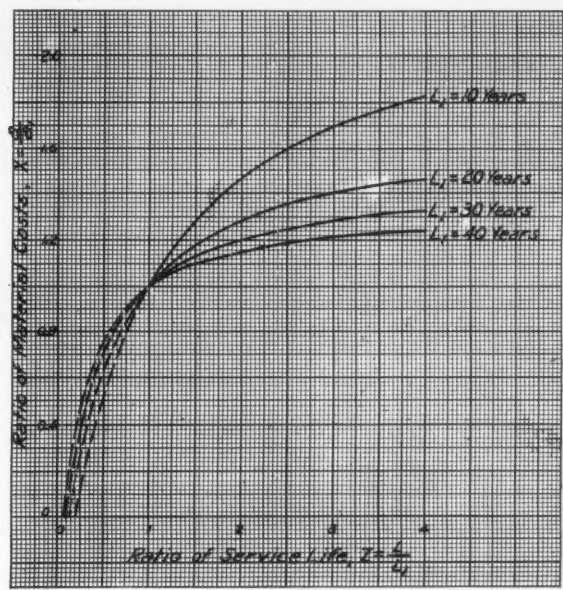
To meet such objection the following expression has been derived for a correction factor, E , applicable to the class B and C coating annual cost graphs of Figures 31 and 32.

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Figure 30—Maximum justifiable material cost increase to secure improved service life.



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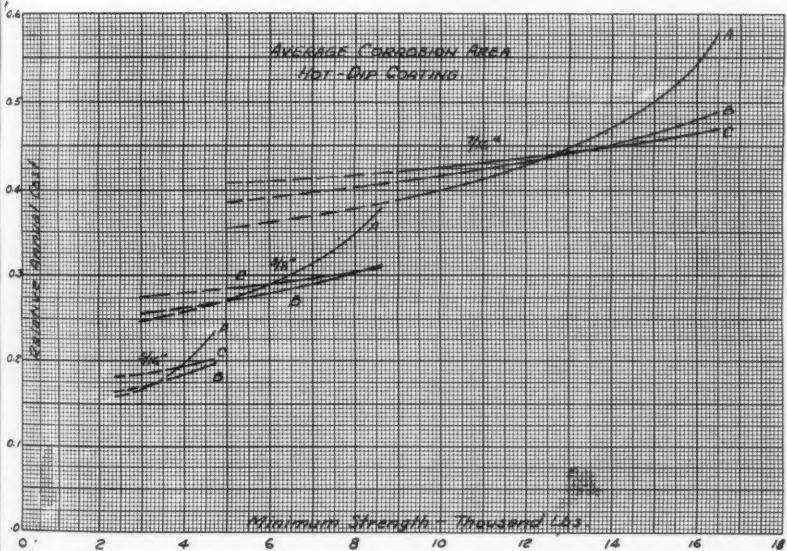


Figure 31—Relative unit annual cost of 7-strand 7/16-inch, 3/8-inch and 5/16-inch hot-dip zinc coated guy wire with grade A, B and C coatings in average corrosion area.

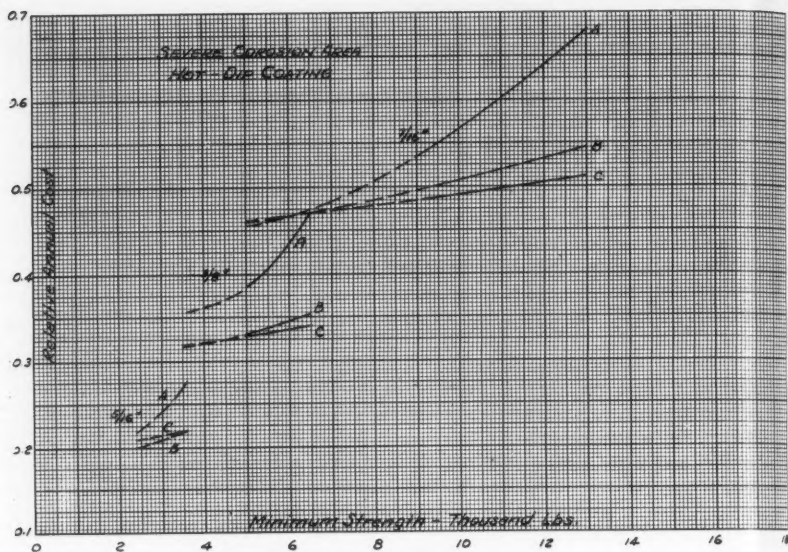


Figure 32—Relative unit annual cost of 7-strand 7/16-inch, 3/8-inch and 5/16-inch hot-dip zinc coated guy wire with grade A, B and C coatings in severe corrosion area.

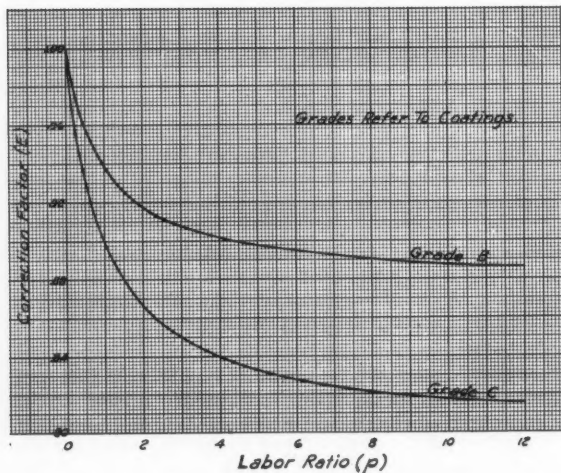


Figure 33—Correction factor (E) for guy wire annual cost curves.

TABLE VIII

Minimum NESC Strength Requirements for Line and Anchor Guys, for Each Conductor Supported, Under Heavy Loading Conditions

Wire Size (B. or W.P.)	Maximum Tension and Wind Load Lbs.	NESC Construc- tion Grade	MINIMUM STRENGTH REQUIRED (POUNDS)															
			Line Guy-Lead = ∞				Anchor Guy-Lead = 1				Anchor Guy-Lead = ½							
			10' Pull	15' Pull	25' Pull	Dead-End	10' Pull	15' Pull	25' Pull	Dead-End	10' Pull	15' Pull	25' Pull	Dead-End	10' Pull	15' Pull	25' Pull	Dead-End
No. 6.....	800 (45)	B	360	480	720	1200	410	630	970	1695	660	925	1465	2685				
		C	275	365	550	915	350	480	735	1290	505	705	1115	2050				
		N	205	285	445	800	270	385	610	1130	405	580	940	1790				
No. 3.....	1000 (47)	B	425	580	875	1500	550	720	1185	2115	795	1135	1810	3360				
		C	325	440	670	1140	415	575	905	1610	605	865	1375	2560				
		N	245	345	545	1000	330	470	750	1410	495	720	1165	2240				
No. 1/0.....	1400 (54)	B	560	770	1190	2100	735	1035	1630	2975	1080	1555	2490	4695				
		C	430	590	910	1600	560	790	1240	2260	825	1185	1900	3580				
		N	335	475	755	1400	450	650	1045	1980	680	995	1620	3130				
No. 4/0.....	2000 (61)	B	765	1065	1665	3000	1015	1440	2290	4245	1510	2185	3525	6620				
		C	585	810	1270	2285	770	1100	1740	3240	1150	1660	2685	5120				
		N	460	660	1060	2000	625	910	1475	2830	955	1405	2300	4480				
1½" Messenger with 350 MCM 22 KV. Cable	9000 (150)	B	3100	4450	7150	13500	4450	6135	9960	19125	6460	9490	15550	30300				
		C	2360	3390	5450	10300	3390	4670	7580	14560	4920	7230	11850	23100				
		N	1950	2850	4650	9000	2700	3975	6525	12750	4190	6210	10250	20200				

1. Numbers in parentheses are the wind pressure in pounds for 100 feet of conductor or cable and messenger at 4 lbs. per sq. ft. of projected area.
2. For class C and B construction wind load is multiplied by 1.78 before combining loads.
3. Reduction of wind loading due to angularity of incidence is neglected.
4. Guy attachment is assumed at point of application of loading.
5. Minimum strength required is 100 percent for grade N construction.
Minimum strength required is 114.3 percent for grade C construction; NESC requirement.
Minimum strength required is 150 percent for grade B construction; NESC requirement.

$$E = \frac{k' + p}{k'(1 + p)} \quad [21]$$

Here k' is the material cost ratio of any strand with class B or C coating to that of the same size strand with class A coating. In Figure 33 are plotted these correction factor graphs versus labor ratio using the same manufacturers' prices as used before for values of k' .

Examination of the cost graphs of Figures 31 and 32 in conjunction with the correction factor graphs, Figure 33, shows that the most heavily coated strands perform most economically in severe exposure, the economy increasing considerably at the higher labor ratios. The case is the same for areas of average exposure, though to a lesser degree.

Conclusion

No facile, compact generalizations

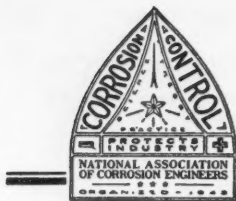
are possible. It may be said in conclusion that we are attempting to collect the necessary factual data and devise simple, easily applicable methods for analyzing quantitatively the various phases of the overhead line maintenance problem.

The results presented are only partial and the data perhaps meager. It is presented for consideration and discussion by those similarly situated.

Acknowledgement

The author is greatly indebted to Mr. E. W. Oesterreich, who sponsored this work and whose ideas were freely used through this paper.

Indebtedness is also acknowledged to Mr. Rolf Selquist, Copperweld Steel Company, for his valuable suggestions and assistance in the guy-strand tests.



NACE News

LOCAL SECTION ACTIVITIES

John W. Nee, Technical Director of the Napko Paint and Varnish Co., Houston, Texas, presented an informative paper, Paint as a Tool of the Corrosion Engineer, during the Houston Section meeting held April 28. Forty members of NACE and guests attended the dinner meeting, which was held at the Houston Engineers' Club.

Mr. Nee traced the history of resins used as pigments from 1908 up to the present, and dwelled upon the latest discoveries and usages of chlorinated rubber, phenolic resin and vinyl resin. Each fits into a definite pattern of application and service for coatings applied to metal surfaces. He stressed that there is no all-purpose coating system, and each installation must be dealt with as a complete and individual problem, and fully understood before a system can be adopted. To support his discussion, Mr. Nee showed panels of various coating systems tested under tide water conditions on the Florida Coast. He also showed pictures revealing the corrosion resistance of chlorinated rubber to aqueous and acid environments.

During the discussion which followed presentation of the paper, Mr.

• **Maynard H. Jackson**, Hill-Hubbell & Co., Division of General Paint Corp., who so ably handled the chairmanship of the Exhibits Committee for the highly successful 1948 NACE Conference and Exhibition held in St. Louis, has been named General Chairman of the 1949 All-Corrosion program of the Association, which will be held April 11 through 14 at the Netherland Plaza Hotel, Cincinnati, Ohio, it was announced by A. B. Campbell, Executive Secretary of NACE. Mr. Campbell also announced that N. E. Berry, Servel, Inc., Evansville, Ind., was appointed Technical Program Chairman for the 1949 Conference, and O. E. Murrey, Midwestern Engine and Equipment Co., Tulsa, Okla., was named Chairman of the Exhibits Committee.

Nee reported that as yet researchers have not found a single paint capable of withstanding high temperatures under atmospheric conditions, such as for use on smoke stacks. He said that all paints recently tested by a committee of the Paint, Varnish and Lacquer Association broke down when submitted to alternate heating and chilling with water—a test made to simulate effects of rain on a stack under high temperature.

A short business meeting, over which Hugh Waldrip, Gulf Oil Corp. presided, preceded presentation of the paper by Mr. Nee. During the meet-

ing it was tentatively decided to hold the next Section meeting June 19. C. W. Scammon, Houston Oil Field Material Co., was named Chairman of the Program Committee for the next meeting. No technical session is planned for the June meeting, but arrangements are under way for a barbecue and general get-together.

Tulsa Section held a meeting in conjunction with the International Petroleum Exposition and Congress May 20. R. L. Bullock presided over the meeting, which was held in the South Auditorium of the Tulsa High School. Two papers were presented. George L. Crain, Interstate Oil Pipe Line Co., Shreveport, La., presented the paper, The Installation and Performance of Scale Traps in Sour Crude Service, and Scott P. Ewing, The Carter Oil Co., Tulsa, read the paper, Cathodic Protection of Castings in Loudon Field (Illinois), which he had prepared in collaboration with J. F. Bayhi, also of Carter Oil Co. Mr. Ewing originally presented this paper at the national meeting of the Association, held in St. Louis, and the paper is reproduced in this edition of Corrosion. During the business meeting it was voted to hold the next meeting at 7:00 p. m. in the Burlingame Hotel, Bartlesville, Okla. James L. Hart of the National Zinc Company, Bartlesville, will present a paper entitled "Corrosion Problems in the Manufacture of Sulfuric Acid."

New Officers of the North Texas Section, Chairman Tom R. Statham, Magnolia Pipe Line Co., Dallas; Vice Chairman James A. Clay, Jr., Service Engineers, Inc., Fort Worth; Secretary Treasurer C. I.

Sims, Consulting Engineer, Dallas, and Assistant Secretary Treasurer L. C. Starbird, Southwestern Bell Telephone Co., Dallas, officially took over their respective duties at the May 27 meeting of the Section. They had been elected April 29. Members voted that meetings of the Section be held the last Thursday in each month. However, there will be no meetings of the Section during June, July and August.

Shreveport Section held a dinner meeting in that Louisiana city May 13. The principal speaker was Wm. F. Levert, Corrosion Engineer, United Gas Pipe Line Co., who read the paper, Utilization of Electrically Insulated Couplings in Corrosion Control. Mr. Levert originally presented the paper at the South Central Regional meeting in Houston, Texas, Sept. 7, 1947. The paper was published in entirety in the January 1948 issue of Corrosion (Vol. 4, No. 1, pp. 24-28).

San Francisco Bay Area Section will meet June 15 in the auditorium of the Pacific Gas & Electric Co., building in Oakland, according to an announcement made by A. Wachter, Shell Development Co., Emeryville, Calif., Section Chairman. The speakers, H. C. Snead and C. S. Hamilton, will talk on various aspects of corrosion preventative maintenance employed on the San Francisco-Oakland Bay Bridge. In addition, a sound film, "Must It Rust," dealing with application and benefits of hot dip galvanizing, will be shown. The film is being loaned to the Section by the American Hot Dip Galvanizers Association.

Cleveland Section met May 24 at the Carter Hotel in that Ohio city, according to a report made by Section Secretary Carl E. Heil, Heil Process Equipment Corp. The main business on the agenda was election of new officers for 1948-49, and they are as follows: Chairman, D. J. Connelly, William & Co., Inc.; Vice Chairman, H. H. Febrey, American Steel & Wire Co.; Secretary-Treasurer, E. W. Vereeke, Heil Process Equipment Co. The speaker of the evening was H. A. Robinson, The Dow Chemical Co., Midland, Mich. His topic was Galvanic Anodes in a Cathodic Protection System. The meeting was the last in the 1947-48 term. The next meeting is scheduled in the fall.

Chicago Section held its final meeting of the 1947-48 term on May 20. A social get-together preceded the dinner meeting. William F.

Croft, Standard Oil Co., of Indiana, Pipe Line Division, presented a paper on Potential Measurements in the Field. New officers for 1948-49 were installed. They are as follows: Chairman, J. P. Casey, Jr., Crane Co.; Vice Chairman, Victor J. Payton, Commonwealth Edison Co.; Secretary, E. F. Jablonski, Hunter Laboratories; Treasurer, J. F. Kaszynski, Witco Chemical Co. The Section will resume technical sessions in the Fall.

St. Louis Section held a dinner meeting May 17 at the York Hotel, for the purpose of completing organization. Business occupied the entire evening, as has been the case at previous sessions. At the last meeting, April 29, By Laws were approved. With organizational problems disposed of, officers are now concerned with technical programs and meetings for the Fall-Spring

DR. NEIL E. GORDON, professor of chemistry, Wayne University, Detroit, Mich., was honored by a group of scientists, convened in Chicago from all parts of the United States, on April 20 for contributions to chemistry and related sciences made possible through a nationally known project which he fathered. The Gibson Island Research Conferences, originated by Dr. Gordon and actively directed by him for nine years, provided the occasion for the program, the principal feature of which was a ceremony renaming the Conferences. By unanimous vote, the scientists responsible for the Conferences decided that they shall be known henceforth as the Gordon Research Conferences.

A scroll to signalize the name change and the reasons for its adoption was presented to Dr. Gordon at the meeting, which took place at a dinner in the Hotel Stevens before some 500 leaders in the field of chemistry and its closely related sciences. A large number of these scientists were in attendance also at American Chemical Society meetings, which took place in Chicago the same week.

Begun in 1938, the annual summer-long Conferences have had as their primary purpose the bringing together of experts for the pooling of research findings and the stimulation of suggestions aimed at the advancement of chemical frontiers. Gifts from 53 industrial companies and from private research laboratories have aided the work. The Record of Chemical Progress was started to record materials growing out of the Conferences. It is still edited by Dr. Gordon.

During the first nine years, the Conferences were held each summer on Gibson Island, Md. In 1947, the management committee decided to move to larger quarters at Colby Junior College, New London, N. H. Simultaneously, Dr. Gordon asked to be relieved of the active management of the Conferences. This was because of the heavy duties which had come to him in his acceptance in 1942 of the chairmanship of the chemistry department of Wayne University. He has continued to take an active interest in the Conferences program. A technical session on corrosion has been a part of these Conferences for a number of years, and the program for this year appears on the following pages.

term. W. H. Keller, of Johns-Manville, is Chairman of the Section.

South East Region of NACE sponsored the program for the weekly luncheon meeting of the Georgia Engineering Society March 15 in Atlanta. Paul B. Boyd, Georgia Power Co., explained the aims and purposes of NACE and exhibited copies of *CORROSION* and the annual conference program. Mr. Boyd introduced the NACE members at the meeting and then presented Ivy M.

Parker, Plantation Pipe Line Co., as guest speaker. Dr. Parker discussed "Corrosion and Products Pipeline Operations."

CORRECTION

Through an error in preparing the Membership Directory for the January 1948 issue of *Corrosion*, the correct company affiliation of F. M. Ruffing, of Brooklyn, N. Y., was not given. Mr. Ruffing's correct company affiliation is Magnode Products Co., Inc., 139-151 Banker St.

CORROSION CONFERENCE PROGRAM

The program for the 1948 American Association for the Advancement of Science Corrosion Conference now known as Gordon Research Conference has been completed, according to I. A. Denison, National Bureau of Standards, chairman of this year's AAAS Corrosion Conference. This year's program will be held July 26 through 30 at Colby Junior College, New London, N. H. Corrosion conferences have been sponsored annually since 1941 by AAAS. Previously held at Gibson Island, Md., the location was changed to Colby Junior College in 1947.

The papers listed for the 1948 Conference cover two general sub-

jects, Surface Reactions on Metals, and Modern Techniques of Corrosion Research. With the objective of considering the broader aspects of corrosion, invitations to participate in the Conference have been extended to physical chemists concerned with the phenomena which occur on metal surfaces. A limited number of applications from those persons interested in attending the Conference will be accepted. All applications should be mailed to W. George Sparks, Chemistry Department, Rhode Island State College, Kingston, R. I.

The program for the July 26-30 meeting follows:

July 26

Symposium-Critical Experiments in Passivity.

Oxide Films, R. B. Mears, Carnegie-Illinois Steel Corp.

Oxide Films, M. Brown, E. I. duPont de Nemours & Co.

Adsorbed Films, M. G. Fontana, The Ohio State University.

Adsorbed Films, N. Hackerman, University of Texas.

Electron Configuration and Related Phenomena of Metal Dissolution, H. H. Uhlig, Massachusetts Institute of Technology.

July 27

Surface Reactions Occurring in Vacuo

• Success of the U.S. Ordnance Department's "canning" of guns and other items for storage was demonstrated recently when the Army made spot checks at several depot sites. Only slight specks of rust and corrosion were found after about two years' storage of such items as guns, tanks and trucks. This is the first report of inspection results of this storage method made by the Ordnance Department, although the Navy and Air Force have "canned" and "cocooned" ships, planes and other equipment.

and in Low Pressure Gas Atmospheres at High Temperatures, E. A. Gulbransen, Westinghouse Electric Corp.

Surface Free Energy and its Possible Role in Corrosion Processes, A. S. Skapski, University of Chicago.

Depolarizers and the Diffusion Layer of Metal Dissolution, C. V. King, New York University.

July 28

Chemical Activity of Metal Surfaces to Oxygen, T. N. Rhodin, Jr., University of Chicago.

Generalized Theory of Corrosion Inhibition, N. Hackerman, University of Texas.

Measurement of Polarization by the Pulse Polarizer, H. J. McDonald, Illinois Institute of Technology.

Applications of the Pearson Null Circuit

to Corrosion Problems, R. F. Hadley, Susquehanna Pipe Line Co.

July 29

Microscopic and Diffraction Methods Applied to Corrosion Problems, K. H. Storks, Bell Telephone Laboratories.

Correlation of Metallographic Techniques in Magnesium Corrosion Studies, W. S. Loose, The Dow Chemical Co.

Application of the Polarograph to Corrosion Studies, P. Van Rysselberghe, University of Oregon.

July 30

Measurement of Surface Roughness of Metals, T. P. May, The International Nickel Co., Inc.

Weather Factors in Atmospheric Corrosion Tests, O. B. Ellis, American Rolling Mill Co.

AES MEETING BEGINS JUNE 28

The technical program for the American Electroplaters' Society Convention, to be held in Convention Hall, Atlantic City, N. J., June 28 to July 1, has been completed, according to Horace H. Smith, AES General Convention Chairman. The Industrial Finishing Exposition, also sponsored by AES, will be held in conjunction with the Convention. The Ambassador Hotel in Atlantic City has been designated as headquarters and place of registration for the Convention. The program follows:

June 28

Industrial Electropolishing, C. L. Faust, Battelle Memorial Institute.

Electropolishing Silver in Cyanide Solutions, D. Gray, Oneida, Ltd.

Diaphragm Tanks to Eliminate Roughness in Cooper Plating, R. H. McCahan and C. E. MacKinnon, E. I. duPont de Nemours & Co.

Oxidation of Trivalent Chromium in Chromic Acid Plating Baths, R. Seegmiller and V. Lamb, National Bureau of Standards.

June 29

Description, Design and Production Costs of Conveyorized Spray Finishing System, E. P. Schwartz, L. C. Smith-Corona Typewriter Corp.

The Electroplater's Metal of the Future,

- Steel subjected to low temperatures loses its tendency to rust and corrode, according to a report made by Ensign C. W. Mallory, Civil Engineers Corps, U.S. Navy, and recently returned from a second visit to Little America in Antarctica. Equipment purposely left behind by the Byrd Expedition in 1947, displayed no signs of corrosion when inspected early in 1948. In addition to remaining bright, equipment was in perfect operating condition. Dug out of a 10-foot snowdrift, a snow tractor was started up on the fuel, lubrication and storage battery which had remained in it for a year. It was first preheated with hot blasts to remove 4 inches of ice which had accumulated on the instrument panel. A jeep which had been left in a canvas-covered shed started up without preheating, as did two GMC diesel motor 25-30 kw generators. Other equipment which showed no sign of rust and started immediately was a gasoline engine D-6 tractor, a TD-9 International tractor, and battery charging apparatus. Most striking example of the slow rate of deterioration of equipment at Little America, Ensign Mallory reported, is illustrated by a wind-driven generator which has been running continuously without maintenance since it was erected by members of the 1933-34 Byrd Expedition.

F. A. Lowenheim, Metal & Thermit Corp.

The Importance of Acid Ratio in the Phosphatization of Steel, N. F. Murphy and M. A. Streicher, Virginia Polytechnic Institute.

Metal Cleaning, G. B. Hogaboom, Consultant.

June 30

A Circulating Electrolyte Cell for Strip Plating Evaluation, R. A. Dimon, Carnegie-Illinois Steel Corp.

Bright Barrel Plating of Nickel and Zinc, L. A. Chesworth, United-Carr Fastener Corp.

Plating Copper-Zinc Alloys, A. K. Graham, Graham Crowley and Associates.

The Deposition of Metals on Plastics Employing Reduced Copper Films, H. Narcus, Electrochemical Industries, Inc.

Judging the Quality of Plated Parts, W. M. Phillips and F. L. Clifton, General Motors Corp.

Practical Methods of Cost Finding and Estimating on Metal Finishes, A. Bregman, Consultant.

The Spiral Contractometer, a New Instrument for the Measurement of Stress in Electrodeposits, A. Brenner and S. Senderoff, National Bureau of Standards.

Engineering Planning in the Plating Room, S. M. Martin, United Chromium, Inc.

July 1

Project 5—Some Effects of Copper as an Impurity in Nickel Plating Solutions and its Effect on the Salt Spray Resistance of Nickel and Chromium Deposits on Steel, D. T. Ewing and R. Rominski.

Project 6—Determination of the Porosity and Corrodibility of Electrolytic Metal Foils, N. Thorl and D. K. Kelemen.

Project 7—The Effect of Internal Stress on Thickness Determination by the Jet Method, H. J. Read.

Project 9—Physical Properties of Nickel Deposits, A. Brenner and C. W. Jennings.

PERSONALS

John W. Crossett has joined the Development and Research Division of The International Nickel Co., New York, it was announced by T. H. Wickenden, Vice President in charge of that Division. Mr. Crossett will follow railroad development work, and succeeds the late Frederick P. Huston. For the past 15 years, Mr. Crossett had been connected with the Chicago, Milwaukee, St. Paul & Pacific Railroad. Previously he was associated with the Gisholt Machine Co. He received a Bachelor of Chemical Engineering degree from the University of Wisconsin.

A. C. Nelson and **E. B. Ayers**, corrosion engineers formerly associated with the Plantation Pipe Line Co., Atlanta, Ga., have become affiliated with the Trans-Arabia Oil

Co., and are now in Arabia engaged in corrosion work. Both are members of NACE.

A. B. Vestal has been named to the managerial staff of the Firth Sterling Steel & Carbide Corp., McKeesport, Pa. During the past eight years, he served as head of industrial engineering of both the Farrell and Duquesne plants of Carnegie-Illinois Steel Corp, and more recently served on its company staff.

William B. Hubbard, President of the Cherry Rivet Co., Los Angeles, Calif., has been named to the Board of Directors of the California Manufacturers Association.

Lawrence M. Muse has been appointed Assistant to the General Manager, Industrial Division, Sherwin-Williams Co., Cleveland, Ohio.

Harold Vagtborg, President and

Director of Midwest Research Institute, Kansas City, Mo., since its inception on January 1, 1945, announced to the Board of Governors his resignation to permit him to accept appointment, effective September 1, 1948, as President and Director of Southwest Research Institute, Houston, Texas; as Director of the Institute of Inventive Research; and as Director of the Foundation of Applied Research; also as Technical Director of the 3500-acre Essar Ranch, all located just outside the city limits of San Antonio, Texas. All four institutions were founded by Tom B. Slick, oil man and rancher of San Antonio. Dr. Vagtborg will remain as President and Director of Midwest Research Institute until July 1, 1948, at which time he will,

at the request of the Board of Governors, function in an advisory capacity until his permanent successor is appointed. George E. Ziegler, Executive Scientist, will take over the administrative responsibilities of Midwest Research Institute until Dr. Vagtborg's successor is announced.

Roger M. Wheeler, formerly with Sohio Pipe Line Co., St. Louis, Mo., and **Marshall Parker**, previously with Pan American Pipe Line Co., Houston, Texas, have joined the Sales and Service Department of the Cathodic Protection Service Co., Houston. Mr. Wheeler will have headquarters in the newly opened branch office of CPS in Tulsa, Okla., while Mr. Parker will operate from the main office of the Company in Houston.

Earl H. Kendall, Materials Engineer, Consumers Power Co., Jackson, Mich., died at his home April 7 following a brief illness. Born near Peoria, Ill., Mr. Kendall had been associated with the Consumers Power Co., and Commonwealth and Southern Corp., since 1920. For the past 15 years he had been chiefly concerned with overhead line materials and design. Previously he had been concerned with industrial and electrical station design. Responsible for many innovations and inventions, he is widely known throughout the pole line hardware, overhead line, wire and timber industries. A member of the National Association of Corrosion Engineers, he was also an active member of the American Institute of Electrical Engineers and the American Wood Preserving Association. At the time of his

death, he was Chairman of the Edison Electric Institute Line Hardware Subcommittee of the Transportation and Distribution Committee, and Secretary of the Committee on Electrical Conductors of the American Society of Testing Materials. He had also served on several other committees of the latter organization concerned with galvanized products, timber and insulators.

Roland F. Smith, Vice President and General Manager of the Waukesha Foundry Co., Waukesha, Wis., died suddenly April 4 at his Pewaukee, Wis., home. Born in October 1903 in Clinton, Wis., he was the son of C. C. Smith, founder of the Waukesha Foundry, and had been associated in the business with his father since 1922. Mr. Roland Smith had been active in a number of associations.

NEW PRODUCTS, MATERIALS AND SERVICES

—Literature—

A new book, Forming of Austenitic Chromium-Nickel Stainless Steels, compiled to give fabricators of metal equipment a better understanding of the exceptional adaptability of stainless steels to all modern processes of forming, is being distributed by The International Nickel Company, Inc. The book presents a detailed description of the modern forming processes as applied to chromium-nickel stainless steels and as practiced in the fabrication plants of the United States. Bending and straight flanging; forming of curved sections and tubing; deep drawing; die forming; forming of contour-flanged parts, and forming by miscellaneous methods are some of the methods discussed. The specific examples of forming technique are supplemented by details of tool design and tool materials, lubricants, data on dimensions, and consecutive steps in fabrication. The book is available only through International Nickel, and copies, as long as they are available, may be secured in the United States by mailing check of \$4.00 for each copy to The International Nickel Co., Inc., 67 Wall St., New York 5, N. Y., and in Canada by addressing The International Nickel Co., of Canada, Ltd., 25 King St., West, Toronto 1, Canada.

An up-to-date list of all national standards approved by the American Standards Association is available free of charge upon request to the Association at 70 East 45th St., New York 17, N. Y.

Dow Chemical Co., Midland, Mich., has developed a process for depositing a thin film of zinc on magnesium, permitting the electroplating of magnesium by essentially standard techniques. Electrodeposits of any of the commercially plated metals such as chromium, silver, gold, copper, brass, cadmium or zinc can be applied to any commercial magnesium alloy. Excellent adhesion, wear and resistance to accelerated corrosion have been obtained. Parts have been hammered and severely rubbed without lifting the deposit, and the finish has withstood heat, humidity and salt spray tests satisfactorily. While preliminary exterior tests have indicated satisfactory corrosion resistance, it is recommended that exterior uses involving severe exposures be given tests under actual service conditions until additional exterior tests results are available.

Aviation Chemicals Division, R. M. Hollingshead Corp., Camden, N. J., have produced an informative four-page specification sheet listing various types of corrosion preventives identified by their U. S. Government designations. The folder describes the characteristics, lists their uses, explains methods of application and removal and specifies the protection requirements for each. Also listed are corresponding types of the Company's own product, Klad Kote, alongside the government specification. The folder is free upon request.

President's Opening Address at NACE 1948 Annual Conference, Exhibit

By G. R. Olson*

WITH the many new and interesting products on display, with 41 outstanding technical papers ready for presentation, with 17 committee discussions on the agenda, and with the large attendance at this, our opening meeting, I am sure this will be the biggest, and, which is more important, the most instructive annual conference in the history of the National Association of Corrosion Engineers. This is, of course, to be expected, for we are still a young and rapidly growing national association.

Now is an opportune time for our Association as a group as well as each of us as individuals, to summarize the results of the past twelve months, and plan our work for the coming year. By discussing our past work and future plans, with others who have similar problems, much can be done towards eliminating duplication of effort and improving our methods of attack, so that our work in the coming year may be more productive to each individual as well as to the group as a whole.

In the past, our meetings have all been noted for their sincerity, for the lively interest in all ideas, for the free, frank, and open exchange of

ideas; all of which may be summarized as that "something" which makes technical meetings of this type really worthwhile. Once again the stage is set. Let us all join in a spirit of cooperative good fellowship to make the most of the advantages which are here provided.

During the past twelve months, your Association has made substantial progress in all phases of its activities. I am particularly happy to report that the overall financial condition of our Association is very much improved as compared to the situation a year ago. Membership increases have continued even more rapidly than in previous years and now approach a total of 1400. The fifth and last Regional Division was organized during the year and all five groups are now functioning effectively. Although the organization of Local Sections has proceeded at a much slower pace than anticipated a year ago, we now have nine active groups of this type which are contributing a great deal toward our mutual objectives in each of their local areas.

During the year your Association cooperated with the Electrochemical Society in a joint meeting on cathodic protection, which was held in Pittsburgh last December. Twenty

* United Gas Pipe Line Co., Shreveport, La.

nine papers, covering many phases of the theory and practice of cathodic protection, were presented by outstanding authors. Arrangements are being made for publishing those papers in a book which we hope will be available for distribution in the near future.

The 1945 Abstracts of Corrosion Literature were recently published in book form by our Association. It is hoped that sufficient funds will be available in the next twelve months to publish similar volumes for succeeding years. Plans have been perfected for setting up a more complete abstracting service in the Central Office. Several notable improvements have been made in our official journal, CORROSION, and plans have been perfected for further improvements during the coming year.

We now have eleven technical committees organized and many of them are already working on specific problems. The Condensate Well Committee has recently completed its first assignment and it is expected that a report will soon be ready for distribution. I am sure all of you who are familiar with this work will agree that this committee is making a very important contribution toward the final solution of this particular corrosion problem. Your Association, as well as we individuals, are indebted to Walter Rogers and his committee for the efficient and effective manner in which they have carried out this important assignment. They have demonstrated in a practical way, the advantages which are gained by pooling the knowledge and effort of many individual members in a co-

operative study under the auspices of our Association. It is hoped and expected that all NACE committees will, in the future, be equally effective.

A review of our activities for the past five years indicates that we have completed the preliminary organizational stage in our development. The framework of a real national organization has been built up. With increased support of the members and under the able leadership of your new Officers, this organization will, I am sure, be adequately developed to meet the increased demands of a growing national association.

In the very near future, our Association should easily double and treble in size. I personally feel that the total membership will ultimately approach from 25,000 to 30,000. We already have representation in 12 separate industries and 16 foreign countries. I am sure none of us are anxious to obtain new members merely to claim a large membership list. Our only interest in new members should be to obtain the benefit of their knowledge and experience in as many fields as possible. What we need is more members who are truly active for there is no better way to increase the usefulness of our own efforts than to combine them with those of others who are working toward the same end. It seems obvious that no organization such as this can continue to progress successfully unless a large percentage of the Active members are constantly working to promote the objectives for which that Association was organized.

Nearly every month your Officers

and Directors are receiving suggestions that NACE initiate special projects of one kind or another in the interest of developing improved methods of corrosion control. Practically all of those proposed projects are very much worthwhile and should logically be handled by our Association. However, each of them require cash expenditures which are not readily available. Your Officers have felt it unwise to start any particular new project unless reasonable progress can be expected in the immediate future. In other words, we believe that NACE should build up a reputation for getting results on all the jobs it undertakes.

No particular difficulties are usually encountered in appointing committees to handle various technical problems, but it is something else to insure that reasonable progress will be made on each job. In these busy times, it is unreasonable to expect well-qualified committee chairmen to handle all the detail work which is necessary to insure continuous progress on most worthwhile projects. In my opinion, the only answer is for our Central Office to supply a certain amount of help to each committee on such details as can be handled more efficiently in that manner. This means that we need to keep expanding our Central Office, for a few years at least, to handle all such essential work and we must find ways and means to increase our annual revenue proportionately.

I am sure most of you realize that the \$7.50 yearly dues which we Active members pay, is nowhere near enough to support a magazine and Central Office, not to mention num-

erous other activities. The Active Memberships dues were set low to encourage the younger men to join and take an active part in the work so that they would be prepared to carry on our Association's affairs in the future.

From the first it was expected that sufficient advertising revenue could be obtained to place CORROSION on a self-supporting basis. However, it takes time to demonstrate the advantages of our publication as an advertising medium. During the calendar years of 1946 and 1947, we experienced a net loss of about \$3700 and \$2900, respectively, on the Publication Budget. Those losses were made up from other revenue which we had hoped to use for supporting additional technical activities. At this time, I am very happy to report that sufficient advertising has already been sold for 1948 so that we have every reason to believe that our magazine will be self-supporting in the current year.

Our real source of revenue for the support of the Central Office, as well as special technical activities is dues from Associate and Corporate Members. The further expansion of our technical activities will therefore be limited by growth in these types of memberships. Your Board of Directors has approved a program for the current year which provides for reasonable expansion in our Association's activities and includes several important projects which will be beneficial to all of us. However, this program is based on the assumption that we will obtain 100 new paid-in Company Members. Unless the necessary funds are thus made available, our new President

and his Executive Committee will find their hands tied when they are asked to approve the various items in this program. For these reasons, let me suggest that each of you arrange to spend a little time each week, starting now, in carrying this worthwhile message to the management of the companies in your local area.

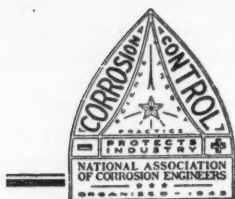
In the past your Officers have found it very difficult to obtain commitments from the Active Members to serve on advertising, membership and other committees which have any connection with sales or promotional work. Why is it that nearly all corrosion engineers believe their assistance will be of little help on any kind of selling job? Most certainly, the best prepared designs in your regular work will not get the job done unless you can get the active support of the officer in your company who controls the purse strings. Our Association is in a similar position, and a certain amount of selling must be done in connection with each technical job. I most certainly make no claim to being an authority on salesmanship, but I am convinced that all we need to do is

present the simple, honest story to the right individual in each organization which will benefit by supporting NACE.

Actually, we have an unusual bargain to offer each of the several thousand companies in this country who are in need of help on corrosion control. No individual company can expect to do much with \$100 per year towards solving their particular corrosion problem. However, if many companies combine this small amount under the direction of the combined skill and experience of many technical workmen, then a great deal can be accomplished under the auspices of NACE for the benefit of all.

In conclusion, let me remind each and every member of our Association that by selling Company Memberships, you will personally gain increased recognition in management circles which will help your work in every way. Let us not forget that increased Company Memberships not only mean more revenue for carrying on technical work but it also means increased active support from management which you and your Association needs.

• Corrosion costs this nation \$3 to \$4 billion annually, according to Kenneth C. Compton, Bell Telephone Laboratories, and a large portion of this sum is expended on preventive measures such as inhibitors and protective coatings. Mr. Compton made this declaration at a recent meeting of the New Jersey Chapter, American Society for Metals, when he presented the paper, *Corrosion of Metals*. In a similar paper, *Selection of Protective Coatings for Metals*, presented at the Symposium on Modern Metals in Cleveland, Ohio, Sept. 1, 1947, and printed in the March 1948 *Corrosion* (Vol. 4, No. 3, pp. 112-122) Mr. Compton estimated the cost of corrosion to the world as upwards of \$10 billion per annum, which sum would be multiplied many, many fold were it not for the use of protective coatings. He estimated that the annual cost of raw materials used in the protective coatings industry in this country alone exceeded \$500 million, and the cost of labor for application of these coatings at several times the cost of the raw materials.



Corrosion Abstracts

ATMOSPHERIC CORROSION

Corrosion in the Tropics. K. G. Compton, Bell Telephone Labs. Paper before Electrochem. Soc., 91st Gen. Mtg., Louisville, Ky., April 9-12, 1947, *Electrochem. Soc., Preprint* 91-35, 631-638 (1947) Apr.

Weather conditions in several tropical locations are described and curves are shown depicting the change of relative humidity over the daily cycle. Presence of condensation on the surface accounts for the severity of corrosion of metals

when not directly exposed to weather. In many tropical islands, coral dust provides a source of chlorides as a corrosion accelerator. Corrosion was found to be most severe during shipment and storage under warehouse conditions. Zinc either as a coat or in die castings, was found particularly susceptible to corrosion by high humidity and condensation. Relative corrosion resistance of various metals is given. Coatings of brass, bronze, cooper, nickel and nickel chromium gave excellent service. Aluminum, magnesium and silver were also satisfactory.

Editor's Note

• A large volume of information is being published currently on the subject of corrosion. Abstracts of this literature are available to NACE through the contributions of a number of organizations. It is the responsibility of the Staff of CORROSION and the Publication Committee to present those abstracts to the membership through the journal.

In an effort to keep abreast of our very excellent abstract service, the Publication Committee has voted to reduce the type from 10 to 8 point in order to present more abstracts per issue. In addition, extra pages are being added to the magazine to catch up with the back abstracts in our files.

For your information we present a list of our abstract contributors, together with abbreviations used following abstract to denote source.

Aluminium Laboratories, Ltd. (The Abstract Bulletin)	ALL
American Society for Metals (Metals Review)	MR
American Society for Refrigerating Engineers (Refrigeration Abstracts)	RA
American Water Works Association (Journal)	AWWA
Battelle Memorial Institute Library (Battelle Library Review)	BLR
British Non-Ferrous Research Association (Bulletin)	BULL
Calco Chemical Division, American Cyanamid Corp.	CALCO
Consolidated Edison Co. of New York, Inc.	CEC
General Petroleum Corp. of California	GPC
International Nickel Company, Inc., The	INCO
Institute of Aeronautical Sciences, Inc. (Aeronautical Review)	AER
Institute of Metals, London, Eng. (Metallurgical Abstracts)	MIM
Institute of Petroleum	IP
McGraw Hill Publishing Company (Electrical World)	EW
(Chemical Engineering)	CE
National Bureau of Standards	NBS
Research Association of British Paint, Color and Varnish Manufacturers (Review)	REV
Revue de Metallurgie	RM
Standard Oil Development Co.	SOD
Universal Oil Products	UOP

Atmospheric Weathering Tests on Anodized Aluminium Reflectors. W. E. Harper, C. A. Morton & P. Smith, *Trans. Illum. Eng. Soc.*, 11, No. 8, 175-201 (1946) Aug.

A series of tests on sulfuric-acid anodized samples have been carried out at various outdoor and indoor stations selected to give the widest range of types of exposure. Some interesting results have been obtained but cannot be briefly abstracted. Full-scale field tests on a statistical basis are planned.—BNF.

Concerning the Oxidation of Aluminum in a Humid Atmosphere (In French). Nicolas Cabrera & Jean Hamon, *Comptes Rendus* (France) 224, 1558-1560 (1947) June 2; *Ibid.* 224, 1713-1715 (1947) June 16; *Ibid.* 225, 59-61 (1947) July 7.

Authors studied oxidation of aluminum at various temperatures. It was found that different methods had to be used below and above 200° F., attributed to the rapidly increased rate of oxidation at higher temperatures. Formulas for estimating the electronic charge, according to Mott's theory of oxidation, are given. Plates coated with almost opaque layers of aluminum were oxidized in the presence of varying amounts of water vapor and the data plotted. A formula for estimating the thickness of oxidized aluminum is given. The amount of oxidation in moist atmosphere depends on pressure and does not agree with Mott's theory of oxidation in a dry atmosphere.—BLR.

BEARING CORROSION

Relation Between Corrosion Rates of Copper-Lead Bearing Alloys and Pure Lead in Solutions of Organic Acids in Hydrocarbons. C. F. Prutton & D. Turnbull, General Electric Co. *Corros. & Matl. Prot.* 4, No. 3, 13-18, 20 (1947) May-June.

Rates of corrosion of two types of copper-lead bearing alloys were measured in copper-saturated solutions of lauric acid plus either acetic or benzoic acid or a mixture of acetic and t-butyl hydroxyperoxide in zylene and white oil. The effect of the following variables was evaluated: (1) speed of rotation of test specimen, (2) effect of depletion of lead from the alloy surface upon the corrosion rate, (3) character and concentration of the acid and of the oxidizing agent, (4) temperature, (5) catalytic effects of salts formed during the reactions, and (6) ratio of volume of test solution to specimen area. With all other factors held constant, the corrosion rate decreased steadily with

loss of lead from the surface of a given specimen and the following relation prevailed in all experiments, excepting those complicated by oxidation of the solvent: $w^2 + aw = bt$, w being corrosion loss per unit area, t being time, a and b constants. It is difficult to draw conclusions about the corrosion mechanism in oil solutions at 140° C. because corrosion and oxidation of the oil proceed simultaneously.

Addition Type Lubricating Oils for Aircraft Engines. W. E. Kuhn, Texas Co., & J. E. Fields, Beacon Res. Lab. Paper Before ASME Aviation Div. & Southern Calif. Section, Coop. Univ. of Calif. *Mech. Eng.*, 69, No. 2, 150-152 (1947) Feb.

Major factors involved in aircraft-engine lubrication and methods available for improving engine maintenance through improved lubrication are discussed. Typical valve-guide corrosion as found in flight and laboratory tests is shown. The possible problem of alloy-bearing corrosion is also included. Bulk-oil temperatures are now below the point where excessive oil deterioration takes place, but higher temperatures may be introduced, additive materials themselves may promote bearing corrosion or the use of coarse-structure alloys may lead to possible bearing corrosion—INCO.

CATHODIC PROTECTION

Calculation of the Cathodic Protection of Non-Insulated Pipelines. V. S. Kal'man, *Neft. Khoz.*, 25, No. 5, 54-8 (1947).

Formulas are derived for determining optimal relationship between power requirements of cathodic protection stations and number of such stations along a pipeline of given diameter, from data available on the specific resistance of the soil.

Selenium Rectifiers. J. Lobenstein, Radio Receptor Co., N. Y. *Mach. Design*, 19, No. 3, 112-114 (1947) March.

Improved characteristics, increase in plate size and plates capable of sustaining high voltage have broadened the field of application of selenium resistifiers. Rectifiers utilize base plates of steel or aluminum on which is sprayed a layer of selenium and a counter-electrode layer of alloy. The base metal acts as one electrode and the metal alloy as the other. The plates require no warming up, efficiency is uniformly high over a wide load range, and there is almost 100% power factor. Characteristics of various types of rectifying equipment are listed. Graphs, charts and photographs.—INCO.

Galvanic Protection of Iron by Magnesium Anodes (In French). Bernard J. C. Raclot. *Metaux & Corrosion*, 22, 28-30 (1947) Feb.

Properties of both zinc and magnesium are considered and pure magnesium is found to have the highest potential. The anode is buried in a mixture of tar and paraffin within a few feet of the pipe.—BLR.

CHEMICAL CORROSION

Corrosion by Chlorine and by Hydrogen Chloride at High Temperatures. M. H. Brown, W. B. DeLong & J. R. Auld. *Ind. & Eng. Chem.*, 39, No. 7, 839-844 (1947).

A number of common engineering materials were exposed to dry hydrogen chloride and to dry chlorine at elevated temperatures in short time tests carried out to determine the relative corrosion resistance and limiting temperatures of serviceability of these materials. Nickel and the high nickel alloys were indicated to be most useful under these conditions. Platinum and gold were found to be resistant to a higher temperature than nickel in dry hydrogen chloride but not in dry chlorine. For some materials the effect on corrosion of dilution of these gases with air, sulfur trioxide or water vapor was also investigated.—CALCO.

Corrosion in Storage Tanks for Crude Sulfate Turpentine. S. G. Norton, Gordon E. Lowe, & George M. Calhoun. *Paper Tr. J.*, 124, 34-35 (1947) May. 1.

Factors which promote corrosion are indicated; preventative recommendations are given. Tests were made by exposing various metals in the vapor above the liquid in a small storage tank. Stainless steel, Everdur, or nickel should be satisfactory construction materials. Copper, aluminum or hot-dipped galvanized tanks might be satisfactory, but should be tested under operating conditions.—BLR.

A Survey of High-Temperature, Gas-Atmosphere Corrosion of Iron-Nickel-Chromium Alloys—Two Parts. J. T. Gow, Battelle Memorial Inst. Paper NACE Ann. Mtg. Chicago, April 7-10, 1947; *Corrosion*, 3, 311-24 (1947) July; *Ibid.* 3, 383-405 (1947) Aug.

Corrosion of iron-nickel-chromium alloys in high temperature gas atmospheres containing oxygen, steam, carbon dioxide, sulfur dioxide, nitrogen, carbon monoxide or hydrocarbon gases is discussed. Results of air-atmosphere corrosion tests on a wide range of iron-nickel-chromium

compositions are presented graphically and discussed. Specimens were exposed continuously for 100 hours to an air-atmosphere saturated with water at 90° F. Test temperatures ranged from 1600 to 2200° F. Alloy composition ranged from 11-31% chromium and 0.0-70% nickel. In general, as the amount of chromium in the alloy was increased, the minimum amount of nickel necessary to obtain maximum corrosion resistance decreased, and visa versa. Maximum scaling resistance was obtained with a wide range of compositions. Studies were also made of the influence of a longer exposure (1000-hours), interrupted heating, and interrupted heating with mechanical shock. Increased protection against scaling was built up in the 1000-hour tests as compared with the 100-hour tests. Interrupted and tumbled exposure increased the amount of corrosion. Adherence of the protective scale layer is of primary importance. Other corrosion studies are reviewed as presented in the literature. 10 refs.

Automobile Exhaust Valve Materials and Lead Attack. R. J. Brown, *Metallurgia*, 36, 149-154 (1947) July.

Two forms of corrosion attributable to lead attack on automobile exhaust valve material are discussed. Various materials are considered; it is stated the ideal valve materials has yet to be discovered. Problem is claimed to be one of faulty combustion rather than faulty metallurgical technique and is, therefore, a problem for the fuel technologist, although the closest cooperation between the designer, metallurgist and fuel technologist is vital if the demands for ever-increasing engine efficiency are to be met.—BLR.

Corrosion of Elektron AM503 Sheet in Chloride Solutions and the Effect of Fluoride Additions and Concentration Variations. C. J. Bushrod, *Magnesium Rev. & Absts.*, 6, No. 4, 132-138 (1946) Oct. Large fluoride additions to the solution inhibited attack, but smaller concentrations were dangerous as they concentrated the attack. Concludes with a theoretical discussion and deductions as to corrosiveness of welding flux residues.—BNF.

Scaling Behavior of High-Strength Heat-Resisting Steels in Air and Combustion Gases. W. Stauffer & H. Kleiber, *J. Iron & Steel Inst.*, 156, 181-188 (1947) June.

A new apparatus and technique for carrying out scaling tests in gas mixtures are described. This apparatus was used for studying the effect of synthetic com-

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burning gases with low, medium, and high sulfur contents on martensite, ferritic, and austenitic high-strength heat-resistant steels. Results obtained, together with those for air, are presented graphically. The work was done at Escher-Wyss in Switzerland.—BLR.

Attack of Molten Zinc on Steel in Hot-Dip Galvanizing. H. Bablik, *Metal Treatment*, 14, No. 49, 29-35 (1947) Spring.

Structure of hot-dipped zinc coatings on steel, diffusion mechanism between the zinc and steel, effect of structure of steel on the attack of zinc in galvanizing are discussed. Carbon content in steel has only the effect of increasing the velocity of dissolution when the carbon is present as globular or lamellar pearlite. There is no considerable weight loss increase if carbon is present as troostite or sorbite. If carbon is present in form of cementite needles or graphite flakes there is no marked change in rate of solution in zinc as compared with pure iron. Tables give full data from tests, and structures of the coatings of various types of steel structure are shown. A table gives weight loss of steel with globular and lamellar pearlite, sorbite, temper sorbite, quench troostite and martensite structure in sulfuric acid and in molten zinc, and effect of galvanizing on hardness of steels of these various structures. Structures of zinc coating on cast iron (graphite flakes seen in latter) and on pig iron are also shown.—INCO.

Corrosion Resistant Cements in the Plating Room. Vincent A. Curil, *Corros. & Matl. Prot.*, 4, 19-20 (1947) July-Aug.

Major problems in many plating rooms—the handling of corrosive solutions in regard to their effect on pitting and erosion of floors, destructive attack in drains and developments of leaks with resulting loss of solution from pickling and plating tanks—are given. How they can be overcome and why they are important in electroplating operations are outlined.—BLR.

Corrosion. M. G. Fontana, *Ind. Eng. Chem.*, 39, 87-88A (1947) June.

A combination of corrosion and mechanical removal by slurries or rapidly moving liquids, of the protective layer created by corrosion, increases the rate of deterioration predicted by static corrosion tests. Erosion-corrosion test equipment which simulates actual operating conditions, has been devised to solve this problem. The equipment consists of a 30-

gallon, glass-lined tank, neoprene hoses, a Chlorimet 3 pump, and a non-metallic housing for the test specimen. The pump recirculates the liquid or slurry in the tank. Pump and test specimens are the only metallic parts in contact with the solution. Two photographs of the equipment and graphs representing the effect of cooper in sulfuric acid slurry on 18-8S molybdenum stainless steel and the effect of pH on steel are included.

Treatment of Magnesium in Chromic Solutions. J. Frasc, *Metaux et Corrosion* (France), 21, No. 245, 11-18 (1946) Jan.; *Chimie et Industrie* (France), 57, No. 5, 463-464 (1947) May.

Principal advantages of galvanic processes over chemical processes are as follows: (1) Baths used in galvanic processes do not attack the metal as seriously as those used in chemical processes; thus provide protection for high precision pieces, calibrated within a few microns. (2) Thickness and porosity of the coating can be regulated by variation in the time of treatment, electrical conditions and oxidizing power of the solution, thus obtaining smooth coatings, protective in themselves, or more porous coatings which form excellent bases for paints. (3) Contrary to the results of chemical processes which require several solutions for different magnesium alloys, the galvanic process requires only one solution for all magnesium alloys whether rolled, forged, sand cast in a chill mould or under pressure. (4) The solution used for galvanic treatment attacks neither iron, aluminum, copper nor their alloys. Magnesium parts already assembled with these metals can be treated, thus avoiding deterioration of the protective film during assembly. (5) Solutions used for galvanic treatment are easily maintained and regenerated, which means that the consumption of chromic oxide in grams per square meter is very low. (6) Corrosion resistance of magnesium parts treated galvanically is vastly superior to that of chemically treated parts. Protective coating can be further reinforced either by sealing with paraffin or applying paint.—ALL.

Periodic Cleaning of Drill Pipe. L. R. Jackson, H. M. Banta & R. C. McMaster, *Drilling Contr.*, 3, 50-53 (1947) June 15.

Seventh report from Battelle Memorial Institute is concerned primarily with a preliminary laboratory investigation of the influence of periodic cleaning upon the corrosion-fatigue operating life of

steel in salt water. The tests reported indicate that such cleaning does not damage drill pipe, and probably adds to its operating lifetime.—BLR.

Dissolution of Gold in Cyanide Solutions. P. F. Thompson, Electrochem. Soc., New York. *Electrochem. Soc. Preprint* 91-26, 27 pp. (1947).

Process is first considered from a theoretical point of view, and then investigated experimentally. Results have value not only for the cyanidation of gold ores, but also for the information they provide concerning corrosion of gold.—BLR.

Anodic Behavior of Mild Steel in Strongly Alkaline Solutions. Chas. D. Weir, *Nature*, 160, 259 (1947) Aug. 23.

Results of experiments are outlined and charted.—BLR.

Chemistry of the Corrosion of Zinc in Aqueous Solutions (German), F. M. Aebi, Thesis 1946 (University of Berne, Switzerland, 100 pp.).

Experiments in the corrosion of zinc in water, in solutions of sodium-chloride and/or zinc chloride and in alkaline sodium-chloride; effect of carbonic acid. Discussion includes consideration of the mechanism of zinc corrosion in 0.5N NaCl solution.—BNF.

Precious Metals in the Chemical Industry. E. M. Wise, Paper before Intern. Cong. of Corros., Paris, 1947. *Steel*, 121, No. 13, 200 (1947) Oct. 6.

Practical large-scale applications of the precious metals, in particular of the platinum metals and alloys, based on their corrosion resistance and catalytic activity are described. General chemical properties and specific behavior toward various corrosives at ordinary and elevated temperatures are outlined. Among uses mentioned are: frangible disks, high temperature corrosion uses (including handling of glass), plating, dental uses, electrical contacts, catalysis, rayon spinnerets. 56 refs.—INCO.

Mechanism of Corrosion Fatigue of Steel in Acid Solution. M. T. Simnad & U. R. Evans, *J. Iron Steel Inst.*, 156, No. 4, 531-539 (1947) Aug.

Corrosion fatigue in hydrogen-chloride shows certain analogies to, but also marked differences from that in potassium chloride. At the end of an incubation period, rounded pits develop into cracks, the residual strength sharply declines, the rate of chemical corrosion (hitherto constant) greatly increases, and the poten-

tial drops; these four changes occur sooner at high than at low stress ranges. A cathodic current can prevent detectable chemical attack but does not greatly increase life. The results are best explained by the changes produced by stress within the metal, in contrast to a rupture of films, which may often be important in neutral solutions.—BNF.

Diaphragm Control Valves—Corrosion Forum. A. J. Koch, Ewart, Healy & Koch, Inc., *Chem. Eng.*, 54, No. 6, 207-208+ (1947) June.

Designs and materials of diaphragm control valves used for gases, wet and dry, acids and other materials are discussed, for both high and low temperature service. Conditions requiring 18-8 Types 304, 316, 347, 440, Monel, Hastelloy B and C, Misco-carbon (20% chromium—9% nickel), 2 to 3½% nickel steel bodies and/or trims are enumerated. Hardened trim is used where erosion is a factor. Below 100° F. 2½ to 3% nickel steel is used with Type 304 stainless trim, if there is no erosion. Where poisonous materials or a very valuable product are involved, a bonnet with a bellows seal of Types 347 and 304 stainless and bronze are used. Monel bellows have not yet been produced in suitable form for this use, so that this type valve can be used only where service involves chemicals which do not corrode Type 347 or 304 stainless. Chemicals covered include: wet and dry chlorine, hydrogen chloride (dry), hydrogen fluoride, nitric acid, sulfuric acid, acetic acid, propane (2 to 3½% nickel steel bodies), sulfurous acid.—INCO.

Proportioning Pumps—Construction, Performance, and Application. R. McFarland, Jr., Hills-McCanna Co., *Chem. Eng. Prog.*, 1, No. 2, 12-16 (1947) Feb.

Typical constructional features of variable-stroke pumps are described, and the pumping characteristics are outlined in relation to their selection and use. The use of metering pumps in proportioning problems is described. Since the main field of application of metering pumps is in chemical use, the metering pump design must be flexible enough to permit selection and application of all different types of alloys to withstand corrosives successfully. The liquid-end design of a metering pump must be such that it can be fabricated economically from a wide selection of alloys, and the peculiarities of fabrication and the ability of the alloys to work with each other, both mechani-

cally and chemically, must be kept in mind. Nothing on materials specifically. A great deal on design and operation.—INCO.

Hydrogen Peroxide for Propulsive Power—Production and Use by the Germans During World War II. L. McKee, USN, Paper before ASME, Ann. Mtg., NYC Dec., 1946. *Mech. Eng.*, **68**, No. 12, 1045-1048 (1946) Dec.

Production of hydrogen peroxide, its characteristics, uses in airplane, torpedo drive and for submarine propulsive power by the Germans are described. Materials used for handling and storing it include stainless steel and 99.6% pure aluminum. In a triple-feed pump for pumping hydrogen peroxide, diesel oil and water in a submarine hydrogen peroxide power plant, Ingolin pump parts, piping and catalyst chamber are stainless steel. Diagram shows complete-cycle engine using hydrogen peroxide.—INCO.

Heat Resistance. W. Stauffer & H. Kleiber. *Iron & Steel*, **20**, 425-428; discussion, p. 407-409 (1947) Aug.

Data are given regarding the resistance of well known heat-resistance steels to chemical attack by air and by sulfur-bearing combustion gases. The investigations were carried out on the Escher-Wyss gas turbine at Zurich, the design of which is briefly described.—BLR.

Investigation of Cavitation in Aluminum and Zinc Alloys. H. Nowotny, *Metallforschung* (Germany), **1**, 182-192 (1946); *Chem. Absts.*, **41**, No. 13, 4079 (1947) July 10.

A discussion of the pitting of alloys as a result of surface cavities and the extent to which chemical corrosion is involved in such processes. Relationship of the zone of destruction to the pressure was determined for circular samples. A systematic investigation of alloys, particularly of aluminum and zinc, was conducted to determine the influence of surface condition as well as individual structures upon cavitation attack. In this it is shown that the grain structure as well as the nature of the surface is of decisive significance for cavitation behavior. The primary precipitated silicon crystallites in hypereutectic aluminum-silicon alloys were practically unattacked in contrast to the eutectic. The very hard compound Al_3Ti behaves in a similar manner, while the softer phases even with small vibrational amplitude are very badly disintegrated. The primary precipitated alumi-

num mixed crystals, as in aluminum-magnesium or aluminum-copper-nickel alloys, were similarly crumbled and the surface was destroyed as was true of the crystallites of pure aluminum. The influence of pores and pipes present in the material upon resistance to cavitation is considerable. Dense, pressed structures behave better under weak loading than cast alloys. Fuels such as benzene (benzene) tend to destroy materials by cavitation but considerably less than water. Even hot benzene had little destructive effect upon alloys having low cavitation resistance.—ALL.

Protective Film on Aluminum. IV. Some Experiments on the Adsorption of Chloride Ions on the Protective Film on Aluminium and Its Effects. F. Pavelka, *Kolloid-Zeitschrift* (Germany) **1944**, No. 109, 145-149; *Chem. Zent.* (Germany) **1**, 13 (1947); *Chem. Absts.* **41**, No. 16, 5002 (1947) Aug. 20.

A sensitive procedure for carrying out the reaction between chlorine ions and silver ions is described. Curves representing the data are discussed in the light of the following considerations: (a) the decrease in the chlorine ion concentration in an oxidizing bath as a result of deposition or adsorption at the anode as a function of time, (b) the analytically determined amount of chlorine ion on the anode as a function of the chlorine ion concentration in the oxidizing bath, and (c) the characteristic oxidation current curves at different concentrations of chlorine ion in the oxidation bath. This behavior in the electrical oxidation becomes especially clear by observation of the time required for the attainment of a certain current density or the slope of the oxidation curve in certain defined regions. It follows that observation of the behavior during the electrolytic formation of a protective film on aluminum, affords a very sensitive means of detecting the presence of chlorine ions.—ALL.

Sulfur Dioxide vs. Materials of Chemical Plant Construction. W. E. Pratt, *Chem. Eng.*, **54**, 221+ (1947) July.

Part I of a symposium in which manufacturers of typical materials evaluate their products for service involving wet and dry sulfur dioxide and sulfurous acid. Includes article on "Nickel, Nickel Alloys," by W. Z. Friend; and "Silicones," by J. A. McHard.—BLR.

The Ion-Exchange Process Has Matured. F. R. Riley & W. E. Sanborn, Am.

Cyanamid Co., *Sugar*, 42, No. 7, 24-29 (1947) July.

Investigations on the technological and economic aspects of the ion exchange process in laboratory, sugar cane, beet and syrup factories as well as in large scale pilot plants are reported with full data. The advantages are explained and the flow diagram of a six-bed unit for juice or sugar purification is shown.—INCO.

Corrosion Tests on Cold Rolled Acid Resisting Chromium-Nickel Steel. P. Schafmeister & A. Gotta, *Archiv Eisenhüttenwesen*, 5, No. 8, 427-430 (1932).

Study of 18-8 steels for behavior in sulfuric acid. Corrosion resistance of these steels depends on the intact condition of their passive protective film. The latter heals quickly after it has been injured or even removed by mechanical or chemical effects. The superiority of molybdenum containing chromium-nickel steels in cold sulfuric acid is attributable to their stronger tendency toward passivation. Cold working without subsequent heat treatment invariably lowers the resistance to activating acids. 7 refs.—INCO.

Minute Amounts of Cylinder Wear Are Measured With a Microscope. C. S. Bruce & J. T. Duck, *Nat. Bur. of Std. Paper before SAE Ann. Mtg.*, Jan. 10, 1947. *SAE J.*, 55, No. 4, 62 (1947) April.

Maximum wear occurred at the combustion end of the cylinder at levels where the rings repeatedly remove both oil and corrosion films. Various studies showed that the corrosion film formed on iron protects the surface from further corrosion. The finding that greater wear occurred with low cooling-water temperatures supports the corrosion-wear theory and indicates that corrosion is most likely to occur during warmup, when temperatures are low.—INCO.

Prevention of Corrosion by Fluorine and Hydrofluoric Acid. M. G. Fontana, *Ind. Eng. Chem.*, 39, No. 3, 91A-92A (1947) Mar.

A useful article touching briefly on the behavior of metals and other materials to fluorine, and going into much greater detail on similar aspects of hydrogen-fluoride. For anhydrous hydrogen fluoride see papers by Holmberg and Prange, and by Fehr, respectively.—BNF.

Some Studies in the Corrosion of Collapsible Tubes. H. Schor & W. M. Sweet, *Proc. Sci. Sect. Toilet Goods Assoc.*, 7, 42-45 (1947); *Chem. Absts.*, 41, No. 15, 4762 (1947) Aug. 10.

An electrometric method is described for determining electrode potentials of aluminum tube materials when exposed to creams in the presence of probable contaminating metals such as lead or tin. The method makes it possible to estimate the suitability of a given tube metal as a package for a product; to estimate the effect of possible contaminating substances on the inner surface of the tube; and to determine the permissible concentration of a depolarizing material (such as a halide salt) in the product formulation.—ALL.

COATINGS

Zinc Plating for Corrosion Resistance and Decorative Finishing. W. F. Coxon, *Metal Treatment*, 14, No. 49, 38-40 (1947) Spring.

In a survey of progress made recently in use of zinc plating as a protective treatment for steel alone or as an undercoating, a German process of plating steel with zinc and then applying chromium plating direct is compared with the usual custom of plating first with copper or brass, then with nickel and finally with chromium. Only 0.0004 inch of zinc plating is needed, whereas nickel plating must be at least 0.0006 inch thick. Low speed of nickel plating and high cost of nickel has resulted in many articles for outdoor use receiving too thin a coat. Weathering tests of nickel-chromium and zinc-chromium plated steel showed the zinc-chromium coating superior for outdoor uses. Results after a 6-month exposure in industrial atmosphere are mentioned. A potential application is for motor car lamp bodies in pressed steel, at present finished black because labor cannot be obtained for the polishing operations necessary for copper-nickel-chromium finish.—INCO.

Plastic Coatings to Control Metal Corrosion. S. P. Wilson, *Org. Fin.*, 8, 39-42 (1947) Aug.

Discusses thermosetting and thermoplastic materials and uses and selection for various purposes. (To be continued.)

A Protective Filming Process for Tinplate. H. R. Clauser, *Materials & Methods*, 26, No. 2, 97-100 (1947) Aug.

Suggests the use of an alkaline phosphate-dichromate-wetting agent bath to add an additional corrosion resistant film to tin plate; thus increasing rust resistance. The film is also desirable under paint.

Composition of solution is as follows:
Lb./100 gal. Gms./liter.

Crystalline trisodium phosphate	20	24
(or anhydrous trisodium phosphate)	(9)	(10.8)
Sodium dichromate	8	9.6
Sodium hydroxide	22	26.4
Wetting agent	3	3.5

Wetting agents such as Drysonol ME dry or Mergol B (duPont) and Tergitol 4 (Carbide and Carbon Chem. Co.) have proved satisfactory in this alkaline solution—the latter giving the brighter surface. During the filming process the temperature of the solution should be kept as high as possible within the range of 140-185° F. Treatment time may be 2 seconds for a brush-type washer, but not less than 10 seconds at 185° F., or 20 seconds at 140° F. for simple dipping.—CEC.

Protection of Ships Bottoms and the Formulation of Anti-Corrosive Compositions. F. Fancutt & J. C. Hudson, *J. Oil & Colour Chem. Assoc.*, **30**, 135-158; discussion, 158-162 (1947) May; *Oil & Colour Trades J.*, **3**, 730-4+ (1947) Apr. 11.

Following a description of the organization of the Marine Corrosion-Committee, a survey of its researches, and general remarks on the protection of ship bottoms against corrosion, details are given of procedures used and results obtained in development of improved anti-corrosive compositions. Results are tabulated, discussed, and illustrated by photographs. Use of paints containing aluminum and other metallic pigments is tentatively recommended. 11 refs.—BLR.

Water Immersion of Metal Protective Paints; Role of Electroendosmosis in Water Absorption and Blistering. W. W. Kittelberger & A. C. Elm, *Ind. & Eng. Chem.*, **39**, 876-881 (1947) July.

Data presented show that over 90% of the total water absorbed by a linseed-oil-type paint coating, under the influence of both a concentration and a potential gradient, was transferred into the film by electro-endosmotic forces. The possibility that the greater resistance to water absorption and blistering of some paint coatings is not so much due to a greater inherent waterproofness as to an appreciably higher electrolytic resistance is suggested.—BLR.

Present Tendencies in the Technique of Electrodeposition. A. Glazunov, *Rev. Met.*, **43**, No. 7 & 8, 214-218 (1946) July and Aug.

A general consideration of production

of corrosion-resistant deposits of good mechanical properties; avoiding porosity; production by electrodeposition of metals not hitherto thus obtained; bright deposits without polishing; highest efficiency of working.—BNF.

Full Automatic Hot Zinc Galvanizing of Tanks. Raymond F. Ledford, *Iron Age*, **160**, 56-60 (1947) July 31.

Explains the advantages of full automatic methods; describes several interesting examples of conveyORIZED tank-galvanizing installations, and comments on makeup and other characteristics of baths for mechanized operations.—BLR.

M. B. V. Process; Application of a Corrosion-Resistant Aluminium Oxide Coating. R. P. Marshall, *Metal Ind.*, **71**, 93 (1947) Aug. 1.

Process, developed by G. Eckert in 1930, produces an aluminum oxide coating on aluminum and its alloys, which although not so hard as an anodized coating, is very resistant to corrosion. Discusses new plant and alloys treated.—BLR.

Solder Stops Steel Tube-Sheet Corrosion. E. R. Stauffacher, So. Calif. Edison Co., *Elec. World*, **128**, No. 7, 66 (1947) Aug. 16.

Of the several protective coatings tested to prevent corrosion on mild steel tube sheets used with aluminum-brass condenser tubes in sea-water, 50-50 solder plus an organic coating was found to be best. The 50-50 solder was applied by metal spray gun after the surface had been thoroughly cleaned with carbon tetrachloride to remove grease, etc., followed by metal grit blasting at approximately 100 psi air pressure. Standard 1/4-inch round wire 40-50 solder was then applied by the metal spray gun to a thickness of from .030 to .040 inch, determined by preliminary tests on steel plates. In addition to the solder and paint coatings described, cathodic protection is also used to minimize galvanic action. This is accomplished by using circular zinc plates 1 foot in diam. and 1/2-inch thick, mounted on the inside of each manhole door. It is expected that the solder coating will last at least two or three years.—CEC.

Continuous Galvanizing. A. D. Stout, Jr., *Iron Age*, **160**, 79-8P (1947) Aug. 28.

A continuous pipe galvanizing process, capable of coating up to 600 tons of 2-inch pipe every 24 hours is described. Developed by National Tube Co., this process is said to produce zinc-coated tubular

products having smoothness, luster and uniformity of coat superior to that produced by earlier batch-type galvanizing methods.—BLR.

A New Zinc-Base Finish for Steel Parts.

J. A. Williams, United Chromium, Inc., *Materials & Methods*, 25, No. 3, 95-96 (1947) Mar.

In tests of 100 different metallic and synthetic coatings (none of which satisfied simultaneously the double requirement of corrosion resistance and attractive metallic appearance) copper, nickel and chromium plated over steel refrigerator shelves were unsatisfactory because no feasible thickness of plate provided satisfactory corrosion resistance at welded joints where the light cross wires are welded to the heavier wires which form the frame. Final choice of finish was that developed by United Chromium engineers, consisting of zinc plating surfaces, forming a clear conversion coating to retard formation of white zinc corrosion products, then applying a durable baking synthetic. In 1945, this process, known as Anozinc, was accepted as standard finish for steel refrigerator shelves by major refrigerator producers. Process is described.—INCO.

Recent Developments in Ready-Mixed Aluminum Paint. R. I. Wray, *The Paint Ind. Mag.*, 62, No. 7, 234-241 (1947) July.

Among factors affecting leafing in paints is the presence of excessive moisture in the paint, which may also cause development of pressure in the container. When water is mixed with finely divided aluminum powder aluminum oxide or hydroxide is formed and hydrogen liberated. However, the aluminum flakes are coated with a thin film of aluminum oxide and a film of adsorbed stearic acid both of which hinder this reaction until a certain point is reached, after which the reaction is accelerated especially at temperatures exceeding 85° F (29.4° C). Tests showed that an increase of temperature to 125° F (51.5° C) of different paints caused an increase in pressure due to expansion of the air and increase in the partial pressure of the vapor of thinner above the liquid. This was followed by a distinct drop in pressure because of oxygen absorption by the vehicle. In paints with higher moisture content this absorption effect was overcome after 48 hours by the reaction of the water with the aluminum pigment. Some paints showed a drop in pressure when cooled to room temperature, equivalent to the amount of pressure caused by air expansion plus vapor pres-

sure less oxygen absorption. Samples which were intermittently heated developed pressure more slowly. Further tests showed that if the total moisture content of the paint does not exceed 0.15 percent, the danger of pressure development under ordinary temperature conditions is very slight. As a safety factor, however, the moisture content of the paint should not exceed 0.1 percent. Moisture in paint may be introduced by the vehicle, the pigment, or container itself. Aluminum paste is slightly hygroscopic and can pick up moisture in storage if it is stored improperly in humid atmosphere.—ALL.

Mechanism of Pigment Action. H. Wagner, *Reichsanstalt Wirtschaftsabschau Chem. Ber. Prof.*, 15 (PB52011), 85-92 (1942).

Knowledge of iron permeability is most important. Complete freedom from pores cannot be achieved with a paint film and it is suggested the surface be treated with passivating solutions (phosphating). Lead-colored pigments in fatty oils are best for rust inhibitions. To save lead, it is recommended that active lead colors be combined with low-lead pigments. Complete avoidance of lead is not recommended. Some consideration is given the electrochemical action of pigments, and various lead-free pigments containing aluminum or iron are evaluated with respect to lead colors. The importance of selecting appropriate base coats for the desired top coat is emphasized. Note is made of methods of evaluating rust inhibiting pigments and the importance of the water or electrolyte content of the pigment and binder is brought out. Factors, as thickness and grain size of pigments which must be considered in a final choice are enumerated.—INCO.

Aluminum-Alloy Pressure-Gage Case. *Instruments*, 20, No. 8, 729 (1947) Aug.

New "Acaloy" gage case is made of a high-compression molded aluminum alloy. Surface of case is treated by a patented process to prevent corrosion, and it is claimed that the case will withstand a 1500-hour salt spray test. Over treated surface is a black baked-on finish. Case is claimed to be weatherproof because it is provided with a synthetic rubber sealing gasket and a stainless steel snap ring. New case is designed to accommodate safety blowout disks, which are supplied when required. Mfg. by Helicoid Gage Co., Div. American Chain & Cable Co.—INCO.

Some of the Effects of Cadmium, Zinc and Tin Plating on Springs. J. R. Gustaf-

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son, Paper before ASTM, Ann. Mtg., Atlantic City, June 16-20, 1947. *ASTM, Abst.*, No. 36, 2 pp. (1947) June.

Electrolytic plating offers an inexpensive method of applying good rust preventives and cadmium, zinc and tin are widely used as protective agents on spring parts. Effects of electrolytic plating on pre-tempered spring steels were investigated. Material design and fabrication techniques, cleaning and plating, fatigue endurance tests, and salt spray tests at room temperatures and elevated temperatures are discussed.—INCO.

Porosity of Electrodeposited Metals: II. Critical Literature Review. N. Thon & E. T. Addison, Jr., *Monthly Rev. Amer. Electroplaters Soc.*, **34**, No. 5, 6 & 7, 568-576, 722-730, 831-842 (1947) May, June, July.

A carefully correlated and critical evaluation of available information covering all aspects of porosity (methods of test, causes, etc.).—BNF.

Methods for the Control of Anodic Oxide Coatings. J. Herenguel & Segond Me-taux, *Corrosion-Usure*, **20**, No. 233, 1-4 (1945); *J. Inst. of Metals & Metall. Abst.*, **14**, No. 12 (1947) Jan.

Simple methods are described for the control of (a) electrical insulation, (b) continuity of coating, (c) corrosion-resistance, (d) wear-resistance, and (e) fastness to light (in the case of dyed coatings). Instead of the salt-spray test, an alternate-immersion test is proposed, in which a 3% salt solution is used and the specimen is immersed for 30 minutes in each hour. For a short-time test, the appearance is noted after 15 days alternatively, the deterioration in mechanical properties after 6 or 12 months may be measured.—INCO.

Liquid Compound Build Up 1/4-Inch Coating in Single Dip. *Machinery*, **53**, No. 9, 176 (1947) May.

A rack insulator and protective coating, Tygoflex Rack Coating, which builds up from 1/16 to 1.4-inches in thickness in a single dip has been developed. After being applied and subjected to heat for a short time, the coating converts to a thick, impermeable insulator, resembling in appearance and physical characteristics a glossy black rubber compound of medium hardness. It will resist the action of all plating-acid or alkaline solutions at temperatures up to 250° F. for an unlimited time. Abrupt temperature changes do not affect it. The base is a new Tygon resin formulation. Mfg. by U. S. Stone-wear Co., Akron, O.—INCO.

Protective Coatings on Bell System Cables. V. J. Albano & Robert Pope, *Corrosion*, **3**, 221-226 (1947) May.

Describes development of various types of metal, plastic, and fabric coatings, and combinations of these materials, for protection of buried lead-covered telephone cables.—BLR.

First Report on Rust Prevention and Water-Proofing Engine Exteriors. E. Molnar, Ordnance Program No. 5728, 144 pp.; *Bib. Sci. Ind. Rep.*, **3**, 703 (1946) Dec. 6.

Results of a test conducted to determine the merits of lacquer-like materials as rust preventive and water-proofing agents for exteriors of engines and electrical systems in vehicles, are given. The materials (names not given) were applied to engines and electrical systems of 1/4-ton 4 x 4 trucks and inspections made weekly until 2000 miles of operations were completed. All four materials proved effective as rust preventives and equally effective as water-proofing agents against water sprays only. Detailed test report given.

Finishing Steel for Decorative and Protective Purposes. Reid L. Kenyon, *Amer. Iron & Steel Inst. Preprint*, **28** pp. (1947).

Reviews developments in nonmetallic finishes electroplated and hot-dip metallic coatings, combined metallic and nonmetallic coatings, porcelain enamels, stainless steel, and special finishes.—BLR.

New Metallizing Technique Homogenizes Alloy Coatings to Eliminate Porosity. J. A. Looney, Alloy Welding & Mfg. Co., *Petro. Processing*, **1**, No. 4, 290 (1946) Dec.

Refinery equipment, from pump rods to fractionating towers, can be protected by alloy trimming, using a new metal spraying process which "homogenizes" the surface after being applied. Coating is superior to more conventional coatings in corrosion and abrasion resistance. Valve life in an hydrogen fluoride alkylation plant was increased from 30-60 days to over three years, and the valves are still in use with no indication of wear. Similar high service was obtained with valves exposed to hydrochloric acid in an isomerization unit. The success of the new process lies in precise control of temperatures and rate of flow during coating operations. Equipment for the method is portable, so that the process can be used for coating large vessels in the field. Technique requires careful electrical preparation of the surface, metal deposition using a special spraying head or by flame-welding, and finishing by heating the deposit until it attains complete homoge-

neity. Illustrations show Hastelloy-coated stud-bolts and samples coated with Stillite VI, resist alloy, Fanweld and Col-nionor V. Process was developed by Alloy Welding and Mfg. Co., Tulsa.—INCO.

Inspection of Exposure Test Panels with Anodic Electrodeposited Coatings. G. Soderberg, Graham, Crowley & Associates, *ASTM Preprint*, 40, 6 pp. (1947)

Deals with the inspection of electrodeposited coatings of zinc and cadmium on steel, exposed out-of-doors. The prime function of this type of coating in outdoor exposure is to provide corrosion protection to the base metal. 11 refs.—INCO.

Experimental Study of the Coating Formed on Nitrided-Steel Piston Rings During Operation in Nitrided-Steel Cylinders. A. R. Bobrowsky, J. Howard Kittel & Charles P. Boegli, Nat. Advisory Comm. for Aero., Washington, D.C., *War-time Report E-143*, 10 pps. (1944) Mar.

Results of investigation indicate coating is formed by local melting or softening of the nitrided surface and subsequent sudden cooling.—BLR.

Corrosion Protection Lengthens Life of Aluminium Transportation Units. J. F. Mason, Jr., *Aluminum & Magnesium*, 3, No. 5, 14-15+ (1947) Feb.

Use of clad alloys, insulating layers between dissimilar metals, primers and paints.—BNF.

Inspection of Exposure Test Panels with Nondecorative, Electrodeposited Cathodic Coatings. H. A. Pray, Battelle Memorial Inst., *ASTM Preprint* No. 39, 4 pp. (1947)

The function of cathodic, electrodeposited metallic coatings used for purely protective purposes is discussed and the way in which they deteriorate on weathering is described. Rating systems are summarized, with particular emphasis on the methods used for the exposure tests of electrodeposited lead coatings on steel. 4 refs.—INCO.

Effect of Surface Preparation on the Durability of Organic Coatings. V. M. Darsey, *Am. Electroplaters Soc., Proc.* 33rd Ann. Conv., 130-140 (1946) June.

Preparation of metal prior to painting: preparation of steel, copper, brass, lead, zinc and alloys and aluminum and alloys.—BNF.

Protective Organic Coatings as Engineering Materials. J. J. Mattiello, *ASTM Edgar Marburg Lecture*, 100 pp. (1946).

A very useful summary, and of value for reference purposes.—BNF.

Summary of Wartime Research on Plating at the National Bureau of Standards. W. Blum, *Am. Electroplaters Soc., Proc.* 33rd Ann. Conv., 16-23 (1946) June.

Electroplating to retard gun erosion; protection of steel cartridge cases against corrosion; applications of magnetic thickness gauge; problems arising from scarcity of certain metals.—BNF.

Plated Zinc-Base Die Castings. *Monthly Rev. Am. Electroplaters' Soc.*, 34, No. 3, 288-318 (1947) Mar.

A symposium of three papers: J. C. Fox (288-297) deals with the production of castings, covering properties and composition of alloys, casting practice and design of casting and die. C. F. Nixon (298-309) deals with plating (copper, nickel and chromium), including the preliminary buffing and cleaning.—BNF.

War-time Plating Developments in England. A. W. Hotherhall, *Am. Electroplaters' Soc., Proc.* 33rd Ann. Conv., 1-16 (1946) June.

Protective coatings (including methods of test); engineering applications of electrodeposition; miscellaneous. 33 refs.—BNF.

Some Fundamental Aspects of the Hot-Dip Galvanizing Process. W. L. Hall & L. Kenworthy, *Sheet Metal Ind.*, 24, 741-752 (1947) Apr.

Summarizes the more important aspects of hitherto unpublished work concerning methods of controlling the properties of galvanized coatings. Results of series of investigations conducted by British Non-Ferrous Metals Research over a number of years.—BLR.

CONSTRUCTION MATERIAL

Fabrication Notes on Corrosion-Resistant Alloys. J. C. Holmberg, Alloy Welding and Mfg. Co., Paper before ASME Spring Mtg. Tulsa, March, 1947, *Petro. Processing*, 2, No. 4, 314-315 (1947) April; *Steel Processing*, 33, No. 5, 285-286+ (1947) May.

Discussion of some of the problems presented in fabrication of pressure vessels from Types 410, 430, 446, straight chromium alloys, Type 304, same plus 2-3% molybdenum and stabilized grades of stainless steels. Type 430, the most popular straight chromium used, must

CONDENSATE WELL CORROSION

Statistical Analysis of Test Containers for Condensate Well Corrosion Studies. V. V. Kendall, National Tube Co., *Corrosion*, **3**, 359-366 (1947) Aug.

Two types of specimens were used in the study of corrosion in the flow lines of condensate wells: a washer type mounted on a rod and a cylinder-type. Each type is described and illustrated, and results of the statistical analysis tabulated and charted.—BLR.

Effect of Carbide Structure on the Corrosion Resistance of Steel. R. W. Manuel, *Corrosion*, **3**, 415-431; discussion, 431 (1947) Sept.

Much experience with oil-well and oil-pipeline corrosion indicates that the carbide structure of the steel has a great effect on corrosion resistance under conditions in which solid corrosion products form on the surface. Well-formed pearlite with lamellae which are long, straight, and continuous are definitely beneficial. Spheroidization of the pearlite removes this effect. Distortion by heating and alloying elements which effect the structure may also be harmful. Many illustrations show results obtained.—BLR.

Corrosion in High Pressure Gas-Condensate Wells—Gulf Coast Area—Parts I. & II. T. S. Zajac, Shell Oil Co., *Oil & Gas J.*, **46**, No. 7, 102-5, 107 (1947) June 21; *Ibid.* No. 8, 127+ (1947) June 28.

Part I. History, scope, causes and characteristics of corrosion in high-pressure gas-condensate wells are presented. Studies show this corrosive action is probably caused by carbonic acid or the lower fatty acids, or by a combination of both. Generally corrosion attacks wellhead equipment and the producing string most severely. Casing corrosion is less severe because of lower flow velocities. Few serious cases of corrosion have been reported in cycling-plant equipment or gas injection wells.

Part II. Two phases of corrosion prevention in high-pressure gas condensate wells are discussed; corrosion-detection and corrosion-alleviation. Christmas tree inspections and tubing-caliper surveys are satisfactory long-time-interval corrosion-control indicators. Exposure coupons and iron analyses are used for short-time-interval checks. Corrosion control by chemical means is used in wells where injection through the annulus is possible. Some satisfactory chemical inhibitors are in use or are being developed. Corrosion-resist-

never be cold-worked, never heated over 1850° F., and when hot-worked must be annealed, sand blasted and pickled, and given a passivating treatment. Most widely used austenitic type is Type 304 with molybdenum added. Since this alloy undergoes carbide precipitation between 1100-1500° F., it must be heated to 1950-2100° F. and rapidly cooled or water quenched. Use of stabilizing elements is mentioned and the need for exact specification of stainless alloys by purchaser. If gauge of bubble cups were heavier and the service subject to shock, the use of welded Types 410 and 430, unheat-treated, would not be satisfactory, and more orthodox methods would be needed. Trouble with faulty heat transfer in pans of 18-8 was alleviated by use of "Triply," in which outside faces are of chromium iron, with a layer of mild steel inside, and handle of 18-8, which has poor heat conductivity.—INCO.

Control of Marine Borers in Plywood.

A. P. Richards & W. F. Clapp, *Trans. ASME*, **69**, 519-524 (1947) July.

Results of a series of tests on plywood veneers indicate that the addition of a siliceous extender to the adhesive used in bonding plywood prevents the penetration beyond the first veneer of *Limnoria*, *Teredo* and *Bankia*. Pholads are able to penetrate in greatly reduced numbers and are considerably dwarfed in size. Illustrated.—BLR.

Is Cast Iron Superior in Corrosion Resistance to Steel? R. W. White, Westinghouse Electric Co., *Materials & Methods*, **26**, No. 2, 82-5 (1947) Aug.

In order to determine the comparative corrosion resistance of cast iron and steel, the bare metals and varnish and enamel coated metals were exposed to the following test conditions: salt fog spray, water vapor, sulfur dioxide fumes, and ultra-violet light combined with periodic water spray. The rusting of uncoated machined samples of iron and steel are found to be practically identical, while shot blasted, uncoated cast iron showed greater corrosion due to increased surface area. Corrosion resistance of coated steel was found superior to that of coated iron. A graph and various tables are included.

Gas Turbines. H. R. Zschokke & K. H. Niehus, *Iron & Steel*, **20**, 398-400; discussion, 407-409 (1947) Aug.

Discusses requirements of a suitable steel for turbines for varied applications. Includes section on corrosion of the combustion chamber.—BLR.

ant alloys are very helpful in alleviating corrosion of tree fittings. More resistant tubing material is needed. The cost of corrosion is discussed. Future work should emphasize long-range corrosion studies. 14 refs.

Review of NGAA Research on Gas-Condensate Drill Corrosion. T. S. Bacon, Lone Star Producing Co., Paper before NGAA 26th Ann. Mtg., Dallas, April 23-25, 1947. *Oil & Gas J.*, 46, No. 12, 257-58+ (1947) July 26.

Developments in the cooperative research project on corrosion in gas-condensate wells since the latest report (Bull. III: 78 (d) (6/15/46) are summarized. The most economical chemical treatment found consists of partial neutralization of the produced water by the addition of soda-ash or ammonia, inhibitors found to be effective are "Kontrol 115", sodium dichromate, bone oil and naphthenic acids. Protective coatings of plastic and alloys are undergoing tests. A laboratory study of 70 different alloys by the U. S. Bureau of Mines reveals not one low-cost alloy that is corrosion-resistant to carbonic acid, propionic acid, or phenols. 13 refs.

Preventing Corrosion in Gas-Condensate Wells. P. L. Menaul, Stanolind Oil and Gas Co., Paper before AIME, Ann. Mtg., New York, March 17-22, 1947. *AIME Preprint*, 19 pp. (1947) Mar.

Discusses the most dangerous form of corrosion encountered in condensate well oil production, the discovery of the agent causing this corrosion and the remedial chemical treatment proved effective by field use. Injection of ammonia hydroxide has proved effective in preventing gas condensate well corrosion. The injection of "Bone oil" is applied to wells producing brines containing calcium and magnesium salts. An appendix gives the apparatus, solutions and procedure for iron determination, and a rapid field test for ammonia.—INCO.

Surface Layers on Steel in Natural Gas-Condensate Wells. Norman Hackerman & D. A. Shock, *Ind. & Eng. Chem.*, 39, 863-867 (1947) July.

Micrographic studies of coupons exposed in the wellhead have lead to a means of classification and prediction of the corrosive character of condensate gas wells. A non-corrosive type of well has been found in which the surface layer formed on steel is thin, adherent and apparently non-porous. In addition at least two types of corrosive wells have been found. An explanation is offered to ac-

count for the differences on the basis of the presence of an inhibitor in the hydrocarbon phase.—BLR.

FUNDAMENTALS

Influence of a Third Element on the Rate of Diffusion of Zinc from Alpha Brass. S. Gertsriken and others, *Isveit. Sekt. Fiziko-Khim. Anal.*, 16, 174-179 (1946).

Effect of additions of tin, nickel, lead, on the coefficient of diffusion zinc from alpha brass was studied by means of vacuum-evaporation method. Tin and lead increase the coefficient, nickel has no effect. The heat of diffusion remains practically constant in all cases.—INCO.

Activation of Copper by Oxidation and Reduction. F. C. Aldred & F. Happey, *Nature*, 5, No. 160, 267-268 (1947) Aug. 21.

Presents results of preliminary X-ray observations on the crystalline changes produced in the metallic and oxide films of copper during the activation process. A probable mechanism of activation is deduced from consideration of these results and those of Garner and Stone.—BLR.

Mechanism of Cavitation Erosion. Thomas C. Poulter, *Frontier*, 10, 7-11, 28 (1947) June.

The above mechanism is clarified by a discussion of the results of the application of pressure to gases in contact with liquids and solids. Penetration of atomic and molecular hydrogen into metal and of water into glass are described. Presence of high-frequency vibrations from a magnetostriction oscillator is shown to have a marked effect on the cavitation erosion of gray cast iron.—BLR.

Thermodynamic Bases of the Theory of Corrosion (In French). Marcel Pourbaix, *Metaux & Corros.*, 21, 121-129 (1946) Oct.-Nov.

Mathematical formulas and electrical data relating corrosion and thermodynamic properties are derived.—BLR.

Influence of Crystallographic Factors on Intergranular Corrosion of High Purity Aluminum. P. Lacombe & N. Yannagaki, *Comptes Rendus (France)*, 224, No. 12, 921-922 (1947) Mar. 24.

It has already been determined that intercrystalline corrosion of aluminum is not diminished by increased purity of the metal. This led to the theory that the origin of the attack might possibly be due to the uniting of adjoining systems. A

a test, samples of pure, rolled aluminum were submitted to prolonged chemical attack in an aqueous solution of 10 percent hydrochloric acid, then recrystallized with coarse grains by cold rolling followed by heating for 72 hours at 600° C. (1112° F.). Before immersion in the acid, the samples were electrolytically polished. After 25 to 30 days a severe attack leading to complete separation of the crystals was observed. The speed of corrosion was increased by anodic attack of the metal in a solution of 10 percent hydrochloric acid under a current density of 10 mA/dm². Deep intercrystalline corrosion was observed at the end of 6 to 8 days of electrolysis. However, all the contours of the grains are not attacked with the same speed. In the course of coarse grain recrystallization of very pure aluminum twinning occurs and perfect resistance to corrosion was observed in the joints separating the two parts of the twin, principally in the case of twins with rectilinear contour. Prolongation of the anodic attack causes disintegration of the crystals themselves by a severe attack on the intercrystalline limits. The conclusion reached is that the origin of intercrystalline corrosion of aluminum of very high purity can be attributed to failure of neighboring systems to join.—ALL.

Deposition of Nickel and Cobalt by Chemical Reduction. A. Brenner & G. Ridgell, National Bureau of Standards, Paper before AES 34th Ann. Conv., Detroit, June 1947. *The Monthly Rev.*, **34**, No. 8, 933-934 (1947) Aug.

A continuation of the work started in 1946 on deposition of nickel from an ammoniacal solution containing hypophosphites. The process now includes deposition of nickel from acid solutions containing 30 g/l nickel chloride, 10 g/l sodium hypophosphite, and 10 to 50 g/l of sodium hydroxyacetate or 10 g/l of sodium citrate at a pH of 4 to 6. All deposits were semi-bright, and the rate of deposition was as high as 0.0006 inch per hour in the hydroxyacetate bath. Good cobalt or cobalt-nickel coatings could not be had from acid solutions but were obtained in alkaline solutions. With nickel chloride in the ammoniacal cobalt bath, semi-bright cobalt-nickel alloys were obtained at the rate of 0.00066 in./hr. Certain metals and radicals, cadmium and sulfocyanide, had a detrimental effect in all the baths; copper and lead were detrimental both in alkaline and in acid nickel baths; zinc reduced the rate of deposition in the alkaline nickel and cobalt baths; and magnesium and ferrous iron had the

same effect in the alkaline cobalt bath only. The deposition takes place only on certain surfaces that catalyze the process, namely on iron, nickel, active gold, cobalt, aluminum, and palladium. Deposition can be obtained on non-catalytic metals such as platinum, copper and brass if momentary contact is made with an electro-negative metal such as aluminum or iron or a thin layer of acatalytic metal such as palladium is first applied to the surface by immersion. No success was had with deposition on plastics.—INCO.

An Improvement in the Technique of the Investigation of Metals by Means of the Electron Microscope, Serving to Shorten the Process. J. Benard, *Metaux Corros. Usure* (France), **18**, No. 48, 49 (1943); *Chem. Zent.* (Germany), **115**, 579-580 (1944); *Chem. Absts.* (USA), **41**, No. 16, 5073 (1947) Aug. 20.

Comparison of photomicrographs made by various methods showed the method of Duffek and Mahl in which the specimen is covered with a solution of collo-dium in amyl acetate, to give the best results. The evaporation of this film leaves behind characteristic interference colors on the surface of the specimen. It is also suitable, for direct examination of aluminum oxide films, in which case the picture does not reveal differences in the thickness of the film but rather in the orientation of texture.—ALL.

Oxidation of Metals. W. E. Campbell & U. B. Thomas, Bell Telephone Lab., Paper before 91st Gen. Mtg., Electrochem. Soc., Louisville, Ky., April 9-12, 1947. *Electrochem. Soc. Preprint*, 91-24 345-361 (1947).

A simple method is described for measuring low oxidation rates at elevated temperatures. The oxidation rate curves for a large number of copper alloys, nickel and stainless steel are presented. With the exception of stainless steel, which conforms accurately to the logarithmic law, and nickel, which conforms approximately to this law, none of the metals conforms to the commonly accepted rate laws.—INCO.

Causes and Prevention of Stress Corrosion in Brass. J. C. Chaston, *Sheet Metal Ind.*, **24**, No. 243, 1395-1401+ (1947) July; Correspondence, *ibid.*, **24**, No. 244, 1621 (1947) Aug.

Author gives a survey of recent theories and investigations relating to the season-cracking of brass. The theory is advanced that since many surface films bear a close relation to the structure of the underlying metal it may be that at places of disorder

(e.g., grain boundaries) the corrosion film is less stable than that which is formed on the more ordered parts, thus providing a selective path for corrosion.—BNF.

Influence of Surface Condition on the Dry Oxidation of Austenites of Nickel-Chromium and of the Method of Finishing Test Specimens on the Mechanical Hysteresis of Steels (In French). P. Chevenard & X. Wache, Paper before Comm. Tech. des Etats et Proprietes de Surface des Metaux Conf., Paris, Oct., 1945. *Journées des Etats de Surface*, (publ. by l'Office Professionnel General de la Transformation des Metaux), 237-241 (1946).

Incomplete results of experiments dealing with the influence of surface conditions on dry oxidation of austenitic nickel-chromium alloys and on the mechanical hysteresis of mild steel (part of a larger program at the Laboratory d'Imphy) are reported with oxidation-temperature and other curves. 1. **Dry oxidation of 19-10 stainless.** Hot-rolled sheets finished by polishing with Emery Papers and degreasing with trichlorethylene and by electrolytic polishing were oxidized. The first stage of the curves are logarithmic. The checking of the oxygen penetration by the oxide layer increases more quickly than its thickness which differs from the parabolic law of Pilling and Bedworth. There was less dispersion of results with the electrolytically polished specimens. Heat of activation deduced from the diagram is noted to be close to that of nickel, or 49,500 cal/at.g. The second stage of oxidation represented by anamorphosed curves, shows that when the oxide film has become almost impermeable, the weight of the combined oxygen represents $7\frac{1}{2}$ times the weight of the beginning of the accelerated oxidation. Curves also show damping curves of microbars machined after annealing, a month after machining, and also after a new anneal in a vacuo at 800° F. and variation of oxidation constant of 19-10 as function of inverse $1/T$ of absolute temperature (first step of oxidation). 2. Curves show divergent values of internal friction of **carbon steels**, as shown in microbars machined and polished after annealing, and same bars annealed in vacuo after mechanical finishing. Bars differed only in presence or absence of a thin cold-hardened skin, being in same physiochemical structural condition. Decrement went from single to double. This increase in mechanical hysteresis is related to internal stresses developed in the thickness of the cold-hardened skin. **Discussion:** In-

duction phenomenon at start of oxidation of special steels is mentioned. Various cases where the Pilling and Bedworth parabolic law is not exactly followed are cited. In 35-10 steel, the induction phenomenon varies regularly with the temperature, but with the 25-20 composition, duration of first oxidation stage becomes more irregular, being more influenced by the lesser considerations of mechanical and chemical preparation of specimens.—INCO.

Activation of Passive Iron. W. H. Cone & Don H. Anderson, *Corros. & Metall. Prot.*, 4, 21-23 (1947) July-Aug.

Presents test for passivity, its possible causes and solution for change to active state.—BLR.

Mechanism of Corrosion Fatigue of Mild Steel. U. R. Evans & M. Ichoraddji Simnad, *Proc. Roy. Soc. A*, 188, 372-392 (1947) Feb. 11; *Phys. Absts.*, 50, No. 593, 139 (1947) May.

Mechanism was established by means of chemical and electrochemical measurements. These are fully described. One aim was to prevent corrosion fatigue by means of cathodic currents. Such a current diminishes the rate of production of iron compounds. Weak currents shorten the life but stronger currents increase it. This is explained. If the current reaches a certain value corrosion cannot be detected, and the life becomes extremely long in neutral potassium chloride.—INCO.

Corrosion. A New Theory for the Passivation and Corrosion Resistance of 18-8S Stainless Steel. Mars G. Fontana, The Ohio State Univ., *Ind. Eng. Chem.*, 39, No. 9, 103A, 104A (1947) Sept.

Studies during recent months in the Corrosion Research Laboratories at The Ohio State Univ. on a fundamental corrosion research project sponsored by the Office of Naval Research, indicates that 18-8S stainless steel becomes passive because of a physically adsorbed gas. At room temperatures specimens of the alloy display passivity upon exposure to air and lose passivity upon exposure to reduced pressure (vacuum). This process is reversible in that the alloy can be passivated, broken down, and so on, by alternate exposure to air, vacuum, air, vacuum, etc. The ready breakdown of the passivity under vacuum at room temperature indicates weak bonds between the gas and the metal, which in turn, indicates physical adsorption. Oxides or chemisorbed gases would be considerably harder to remove or break down, and

this would probably require an elevated temperature. Several passivation treatments were tried during the preliminary phases of this study. The treatment found most effective, based on corrosion tests, is the one which is designated as the sulfuric air treatment. It consists of exposing a specimen of 18-8S in boiling 10% sulfuric acid for 3 minutes, washing thoroughly in water, and then exposing the specimen to air. Similar results are obtained if hydrochloric acid instead of sulfuric acid is used. It is stated that the nitric acid treatment commonly used in industry does not passivate stainless steel, and is a waste of money.—CEC.

Nature and Mechanism of Passivation of 18-8S Stainless Steel. M. G. Fontana & F. H. Beck, The Ohio State Univ., *Metal Prog.*, 51, No. 6, 939-944 (1947) June.

The most effective of the several passivation treatments tried with 18-8S (Type 304) stainless (including nitric acid, potassium chromate, nitric acid plus potassium chromate) was the "sulfuric-air" treatment, which consists of exposing specimen to boiling 10% sulfuric acid for 3 minutes, washing in water and then exposing to air. Specimens were then tested by immersion in 10% sulfuric acid and synthetic ocean water at 50° C. Specimens lost passivity when exposed to a vacuum and regained it upon exposure to air, the process being reversible. Data prove, according to author, that passivation is due to physical absorption of gas, not to formation of oxide films or chemisorption of gas. Further support was found in some success in passivating by exposure to argon gas (chemically inert). Electron diffraction patterns gave no evidence of oxide films. Ordinary mill pickling is considered somewhat similar to the sulfuric-air treatment recommended and is considered more passivating in itself than the common treatment in warm dilute nitric acid, which many people, including author, now consider worthless. Further investigations will deal with ferritic 18-8, work at elevated temperatures, and in high vacuum, as well as with acid methods, such as electropolishing, which activate metals. Specimens polished with Emery paper were not passivated successfully. Vacuum breakdown apparatus and equipment for determining erosion-corrosion resistance of materials are shown. All test results are tabulated. Results of exposure of specimens to air at 870° C. for 1 hr. are included.—INCO.

Rate of Oxidation of Iron-Chromium-Aluminum Alloys. I. I. Kornilov & A. I.

Shpikelman, *Reports of the Acad. Sciences of USSR*, 53, No. 9, 813-816 (1946); Translation by Henry Bratcher, Altadena, Calif., No. 1965, 7 pps.

Resistance of a series of the above alloys to corrosion was determined. The significance of the sigma phase in alloys with 40% chromium and up to 8.5% aluminum, and the optimum composition for heat resistance, are indicated.—BLR.

Hydrogen Overvoltage with Particular Reference to Nickel, Tantalum and Columbium (In French). E. Palmer, Paper before Comm. Tech. des Etats et Propriétés de Surface des Metaux, Conf., Paris, Oct., 1945. *Journées des Etats de Surface*, (publ. by l'Office Professionnel General de la Transformation des Metaux), 266-271 (1946).

Experiments are reported which reveal that overvoltage at low current density (the only case where electrodes are reversible) is a constant of the metal, independent of the current density. This is connected with the capacity of the metal to attract hydrogen in one form or another, the energy for the formation of the hydrides, etc., being furnished by the electrolysis. Nickel, tantalum and columbium were used, and the overvoltage of reversible electrodes was found to be 0.01 volts for nickel, 0.17 volts for tantalum and 0.14 volts for columbium. Tension-current diagrams are shown for nickel in 0.1 N. sodium hydroxide, for tantalum in 0.1 N. hydrochloric acid, columbium in 0.1 N. hydrochloric acid and for polished platinum in 0.1 N. hydrochloric acid.—INCO.

Present Status of Knowledge on Stress Corrosion Cracking of Iron. H. H. Uhlig, Mass. Inst. of Technol., *Rec. of Chem. Prog.*, 8, No. 1/2, 21-23 (1947) Jan.-Apr.

Condensed review of causes of stress corrosion cracking of steel. Stress corrosion cracking of early steam boilers now countered by welding of boilers is mentioned. Chemical reagents are concentrated nitrate solutions at boiling temperatures, concentrated nitric acid at room temperature, hot dilute nitric acid plus manganous chloride at 60-80° C. (except 46% magnesium chloride at 125° C.), nitrates in rain water (attacking bridge cables), hydrogen cyanide (active ingredient in compressed illuminating gas), impurities in steel combined with environmental factors (nitrogen makes steels more susceptible to failure in alkalies and nitrates while low concentration of phosphorous plus nitrogen and aluminum are good). A possible mechanism involves

precipitation of a compound such as an iron nitride at the highly stressed region at base of crack. 8 refs.—INCO.

Overvoltage of Oxygen Ionization and Its Role in Corrosion Processes. N. D. Tomashov, *Compt. Rend. Acad. Sci. USSR*, **52**, 601-604 (1946) (In English). *Chem. Abstr.*, **41**, No. 8, 2340 (1947) Apr. 20.

The following cathodes were investigated: copper, iron, oxidized iron preliminarily corroded iron, cemented iron, cast iron, nickel, chromium, chrome steel, nickel-chromium steel, graphite, aluminum, duralumin, magnesium, oxidized magnesium, zinc, cadmium, lead, tin, cobalt, tantalum, mercury, silver, gold, and platinum, by using a solution of 0.5M sodium chloride +0.005M sodium carbonate +0.005M sodium bicarbonate (pH 9.1) in an atmosphere of pure oxygen with energetic stirring. Analysis of experimental data indicate: 1) the overvoltage of oxygen ionization shows a logarithmic law of dependence upon the density of the cathodic current; 2) the cathode materials studied, if arranged in the order of increasing overvoltage oxygen ionization, show a succession different both from the sequence of non-equivalent stationary potentials in the same solution and from the sequence of overvoltages of hydrogen evolution, in the same cathode materials; 3) the overvoltage of oxygen ionization is much greater than the overvoltage of hydrogen evolution. Results are also tabulated for the c.d. of zinc-cathode couple in a 3% solution of sodium chloride for the different cathode materials. A direct dependence of the efficiency of the cathode material on the overvoltage of oxygen ionization is indicated.—INCO.

An Electron Diffraction Study of Oxide Films Formed on High Temperature Oxidation Resistant Alloys. J. W. Hickman & E. A. Gulbrandsen, General Electric Co., Paper before 91st Gen. Mtg. Electrochem. Soc., *Electrochem. Soc. Preprint*, **91-32**, 467-483 (1947); *Light Metals Res.*, (England) **8**, No. 15, 384 (1947) July 25.

The electron diffraction reflection technique is used to study the structures of the oxides which form on Alchrome-6, Worthite, stainless steels 301, 446 and alloy S-588 in the temperature range 300 to 900° C. (572 to 1652° F.). Photographs of the oxides are taken at the temperatures of formation in order to eliminate the possibility of chemical and physical changes which may occur upon cooling. The structures found are plotted on existence diagrams as functions of time and temperature. Attempts are made to cor-

relate the structure obtained with thermodynamic data reported by other workers. The oxides on all of the alloys over the complete time-temperature range consist of chromic oxide or a spinel type structure which may be a solid solution of two or more oxides. Spectrographic analyses indicate that nickel is absent in the outer oxide layer. There does not appear to be any unique mechanism for the oxidation of ferritic and austenitic stainless steels. Complete or partial conversion of the oxide occurring on Alchrome-6 to gamma aluminum oxide as reported by other workers is not substantiated in this present study.—ALL.

GENERAL CORROSION

Corrosion Processes—The British Contribution to Their Understanding. U. R. Evans, *Mettall. Ind.*, **70**, No. 19, 335-337 (1947) May 9; *Ibid.*, No. 20, 355-357 (1947) May 16.

An historical review of British corrosion research with 78 references, written because of the Centenary Celebrations of the Chemical Society as a part of a series on British contributions to various chemical fields.—INCO.

Chemical Research and Corrosion Control; Some Recent Contributions of a Corrosion Research Group. W. H. J. Vernon, Chem. Lab., Teddington, *J. Soc. Chem. Ind.*, **66**, 137-42 (1947) May; *Condensation, Corrosion*, **4**, 141-148 (1948) Apr.

Sodium benzoate, 1½% is an effective inhibitor for the corrosion of iron, aluminum, etc., in hard water, distilled water or antifreeze solutions of ethylene glycol or glycerine. It is also an effective medium for impregnating wrapping paper to prevent corrosion of steel wrapped in the (dried) paper. Corrosion in enclosed spaces and accelerated atmospheric corrosion tests are discussed. Pretreatment of metal surfaces has been found to be an important factor in paint adhesion. Colar pitches from which acids and bases have been removed have been dissolved in solvent naphtha, and suitable pigment added to give quick drying paints which have given service comparable (as regards corrosion resistance) with alternative bituminous materials. Soils have been type with regard to the possibility of bacterial corrosion, but more needs to be done in this respect. A high speed rotor apparatus was developed to investigate the corrosion resistance of unpainted metals in fresh waters or sea water under conditions of rapid movement. This has also been found useful in investigating coatings as regards adhesion. 17 refs.—CE

Properties and Influence of Several Less Common Elements When Added to Cast Iron. J. E. Hurst, *Pig Iron Rough Notes*, *Heat*, No. 100, 11-15 (1945) Autumn; *Ibid.*, No. 101, 26-33 (1946) Winter; *Ibid.* No. 102, 13-16 (1946) Spring-Summer.

Elements discussed are beryllium, boron, sodium and potassium, magnesium, calcium, zinc, selenium, arsenic, zirconium, cerium, antimony, lead, bismuth and uranium. Effects are reviewed and some compositions and properties are given.

Residual Elements and Gas Contents of Cast Iron. J. E. Hurst, *Pig Iron Rough Notes*, *Heat*, No. 104, 4-15 (1947) Spring-Summer.

Differences in service behavior of cast irons with similar chemical compositions is usually due to structural differences traceable to the effect of small residual elements and dissolved gases present. Examples include Ni-resist pump for chemical liquor with crystals in suspension, which coarse graphite structure made unsatisfactory. Tables give typical compositions and structures. Composition table of British and American cylinder irons includes residual elements and gases present. Chief difference is the presence of more titanium and hydrogen in the British irons. Analyses of two malleable irons also include residuals and gases. Hydrogen content was reduced by annealing treatment. Structures of typical American and British cylinder irons, good and bad Ni-resist structures, and a gray iron with and without a tellurium addition are shown. The rate of scaling of Silal with pearlitic and ferritic structures is graphed. —INCO.

Survey of the Cleaning Methods Used for Iron and Steel Surfaces. Rick Mansell, *Am. Paint J.*, 31, 54, 56, 60 (1947) Sept. 1. Discusses use of solvent cleaners, steam cleaning, phosphoric acid cleaners, vapor degreasing, alkaline cleaners, and electrolytic cleaners.—BLR.

Corrosion Retarding of Aluminum Alloys. Parts I and II. R. Mansell, *Org. Fin.*, No. 8, 25+ (1947) May; *Ibid.*, No. 9, 2+ (1947) June.

Survey of aluminum alloys in relation to corrosion problems: types of alloys, types of corrosion, exposure tests at New Kensington, Pa., (combined industrial atmosphere, salt spray and water deposit conditions), accelerated alternate immersion and salt spray tests, surface treatment, galvanic corrosion tests, and use of organic coatings. In testing for galvanic

couples, rivets of materials to be tested were inserted in Dural panels, which were intermittently immersed in a 20% solution of sodium-chloride for 10 days. Original ultimate strength of Dural was 60,000 pounds psi, with elongation of 18% in 2 inches. After 10 days, specimens with brass rivets had ultimate strength of 29,950 pounds psi, with elongation of 1.6%, those with low-carbon steel rivets, 32,250 ultimate strength and 2.4% elongation, those with 18-8 rivets, ultimate strength of 38,700, and elongation of 3.25%, those with cadmium-plated rivets (which had a coating of 0.0012 inch) ultimate strength of 55,800 and elongation of 16.1%. Potential measurements showed that with a brass combination the Dural anode and voltage was 0.48 volts; with 18-8 stainless, voltage was 0.38%; with cadmium-plated steel, the cadmium was the anode and voltage was 0.15 volts. Photomicrographs showed that specimens with cadmium-plated rivets were the only ones in which intergranular corrosion did not appear.—INCO.

Research on Corrosion Carried Out in Sweden During the War (In French). E. Palmaer, Paper before Comm. Tech. des Etats et Propriétés de Surface des Metaux Conf., Paris, Oct., 1945. *Journées des Etats de Surface* (publ. by l'Office Professionnel General de la Transformation des Metaux), 1946, 272-273.

Research work in Sweden during the war included: determination of hydrogen-overvoltage on graphite and cementite; determination of electrical conductivity of rust; research on the variable composition of thick layers of rust (rust from an economizer tube, from guns which reposed on the bottom of the sea 200 years, and from a sword from Viking time were examined); various projects on speed of corrosion including amount of oxygen absorbed by specimens moistened by various solutions, and speed of corrosion of iron intermittently quenched in different saline solutions; hydrogen-overvoltage and the reversibility of hydrogen electrodes, particularly with reference to nickel, tantalum and columbium; dissolution of zinc in acids; and corrosion of iron in alkaline solutions. 8 refs.

Some Problems in Corrosion. H. O. Teeple, International Nickel Co., Inc., Paper before ASM, Northwest Chapter, Feb. 13, 1947. *Metals Rev.*, 20, No. 3, 31 (1947) Mar.

Corrosion rate depends not only upon the combination of materials in contact,

but also on the temperature, available oxygen, surface velocity, continuity of corrosion resisting film, and heat-treated condition of the corroded material. Experimental work on liquid and gas corrosion problems in the dye, oil refining and copper smelting industries, illustrating the principal causes, and showing how the most economical method of inhibition is determined was outlined. High-silicon iron, high-chromium alloys and copper alloys (as well as nickel alloys) were included in the tests described.—INCO.

Some Problems in Mineralogy and Inorganic Chemistry. M. Fleischer, *ASTM Preprint*, 117, 19 pp. (1947).

Paper supplies a background for the consideration of the nomenclature of the compounds found in studies of boiler scales, corrosion products, and similar deposits met with in industrial engineering practice.—BNF.

Corrosion. D. H. Garside, *Ind. Heating (England)*, 9, 47-50+ (1947) Mar.

The chemistry and causes of corrosion, its prevention and treatment with particular reference to pipes and ducts are reviewed. The metallurgical and economic qualities of several metallic alloys and means of testing their resistance to corrosion are presented. Various types of colloids such as graphite preparations, tannin, starches, and gels have been successfully used as protective agents. Iron is not protected as well by colloids as nonferrous metals but is progressively more protected with increasing concentration of the colloid.

INHIBITORS

Chemical De-Scaling of Boilers. R. H. Burns, *Engrs. D.* (Amer. edition), 4, 259-262 (1947) June, condensed from *J. Inst. Heat & Vent. Engrs.*, 14, 376-403 (1947) Jan.-Feb.

Results of an extensive study, both in the laboratory and in practice on large and small boilers. Over 500 tests on various metals and alloys, using a variety of inhibitors and concentrations, have been made. Results are summarized, typical data tabulated. Recommended cleaning procedures for large and small boilers are presented, including details of suggested control tests. 10 refs.—BLR.

Use of Wetting Agents in Conjunction with Acid Inhibitors. P. H. Cardwell & L. H. Eilers, Paper, ACS Midwest Reg. Mtg., Kansas City, June 23-25, 1947. Abst.

Oil & Gas J. 46, No. 8, 124-5 (1947) June 28.

Corrodibility of mild steel (ASTM A10. 39) in various concentrations of hydrochloric acid solutions containing different inhibitors was investigated. A tested group of heterocyclic nitrogen compounds containing thiourea and symmetrically substituted diethyl, dibutyl and diphenyl thioureas varied greatly in their inhibitive ability. From the measure of the corrosiveness of the hydrochloric acid solutions containing these inhibitors, (3) factors were found to affect inhibition: (1) the size of the inhibitor molecule, (2) the position of a substituted group within the molecule, and (3) the ability of the material to be adsorbed at the liquid-solid interface. In general, the larger the molecule the better the inhibitor. In heterocyclic nitrogen compounds the substitution of a methyl-group ortho to the nitrogen was more effective than in a meta or para position. The presence of an ortho group may increase the strength of the adsorption bond between the nitrogen and the steel, resulting in a more effective inhibitor.

Nitrogen-Containing Organic Inhibitors of Corrosion. Shih-Jen Ch. Iao & C. A. Mann (Univ. Minn.) *Ind. Eng. Chem.* 39, 910-919 (1947) July.

Data are presented to establish a quantitative relation between the cathode potential rise with the addition of inhibitor and its inhibition efficiency. These inhibitors are cathodically adsorbed on metal surfaces. The cathodic inhibitors of inorganic compounds, such as antimony and arsenic salts, form a new metallic cathode, which has a higher overvoltage than the original and so retards the evolution of hydrogen. Nitrogen-containing organic inhibitors on the other hand reduce the available cathodic area for the evolution of hydrogen but do not actually change the nature of the cathode. The adsorption of these inhibitors, although preferential or cathodic in nature, seems to follow Traube's rate of adsorption.

Corrodibility of Metals Used in Boiler Construction in Inhibited Hydrochloric Acid Solutions. P. H. Cardwell & S. J. Martinez, Dowell Inc., Paper before ACS 112th Mtg., New York, Sept. 15-19, 1947. Abst. of Papers, 13-14R.

Corrodibilities of boiler metals in the inhibited hydrochloric acid solutions used to remove deposits and sludge were investigated. Four types of acid inhibitors were used. An arsenic base inhibitor was

taken as an example of the inorganic type of inhibitor, a copper-amine as the organometallic, symmetrical dibutyl-thiourea as the aliphatic, and a nitrogen-sulfur base material as the aromatic. It was found that the corrodibility of the boiler metals varied considerably in the different inhibited hydrochloric acid solutions. In general it was noted that the corrodibility of the metals in 10 percent inhibited hydrochloric acid solutions depended upon the carbon content of the steel. The higher the carbon content the greater was the corrosion rate. Likewise, in weak acid, 3 percent concentration, it was found the silicon content influenced the corrodibility.—BLR.

Use of Chromate Additions in Drilling Fluids. L. R. Jackson & others, *Drilling Contr.* 3, 77-82 (1947) Aug. 15.

Summarizes results of laboratory tests and field observations to date on the use of sodium chromate additions in drilling fluids, to inhibit corrosion-fatigue damage of drill pipe. Tests indicate that chromate additions are highly effective only if used in combination with other recommended drilling practices.—BLR.

Use of Dehydration in Combating Internal Corrosion in Products Pipeline Systems. H. K. Phipps, Socony Vacuum Co., *Corrosion* 3, 458-465 (1947) Sept.

In order to prevent the corrosion and pitting of pipelines carrying gasoline which is water saturated, the Socony-Vacuum Oil Company has for the past 10 years used a dehydration process based on absorption by an alumina bed. The primary function is to lower the moisture content of the product being pumped to a point where the small amount of moisture remaining will stay in solution in the liquid. The dehydration installation consists of six drums equipped with cone bottoms. The absorption medium employed is 4-8 mesh activated alumina, 3000 pounds of which is used in each drum. The alumina bed is supported on a heavy metal perforated plate covered with a stainless steel screen of 40-60 mesh. The dehydration operation is accomplished by pumping the product through three drums operating in parallel. The alumina bed is regenerated after twelve hours service. At present, twelve different products are being handled through the dehydration system and to date inspection of sections of the pipeline have shown no evidence of pitting or corrosion. Another advantage has been the elimination of pipeline scrapers with their

attendant hazards and operating costs. Costs of the dehydration process do not exceed 50c per 1000 barrels of products —ALL.

Literature Review on Corrosion of Metals and Materials by Flue Gas Condensate. H. A. Pray, F. W. Fink & R. S. Peoples, Battelle Memorial Inst. Publication (for AGA), 29 pp. (1947) Feb.

Based on 55 references. Sulfur in fuel gases; properties of the products of combustion of fuels; corrosive properties; comparison of the corrosion data of various investigators.—BNF.

Color Contamination of Petroleum Products Transported by Pipeline. L. V. Sorg & R. E. Dickey. Paper before ACS Midwest Reg. Mtg., Kansas City, June, 1947. *Abst. Oil & Gas J.* 46, No. 8, 124 (1947) June.

A field trial of an experimental alkaline inhibitor, designed to minimize internal corrosion in pipelines transporting petroleum products showed this inhibitor to be quite successful in reducing the amount of sediment removed from the pipeline system. Its use, however, in the pipeline system handling finished petroleum products, ranging from motor fuels to burning oils, gave rise to an unexpected color-contamination problem, which was most noticeable and objectionable in the case of water white products such as kerosene. The dye responsible for this discoloration, identified as p-indophenol, is formed in the strongly alkaline corrosion-inhibitor phase and apparently results from a reaction between an oxidation product of the antioxidant used in motor fuels and phenol naturally occurring in petroleum stocks. These compounds are concentrated by the alkaline inhibitor phase. Concentrations of p-indophenol as low as one part in 5 million impart an objectionable pink discoloration to water white petroleum products. The addition of sodium sulfite to the corrosion inhibitor eliminates the color difficulty without affecting the corrosion-inhibiting quality of the inhibitor.

Corrosion of Metals; Metals in Aircraft Engine Cooling Systems. P. F. Thompson, *Australian Council for Aera.*, Melbourne, Australia. (Report ACA-24.) 54 pps. (1946) May.

Explains the theory of corrosion. Describes a study of inhibitors and their use. An electrochemical technique for the study of corrosion problems is described. Details of its use in study of the growth

and breakdown of metal films are given. The relationship of two types of corrosion to film formation on aluminum is developed and confirmed by the discovery of hydrogen evolution on aluminum during abrasion in neutral liquids containing water. The use of a powder in studying abrasion of films on metals in electrolytes is explained.—BLR.

Arsenic as a Corrosion Inhibitor (for Steel) in Sulfuric Acid. A. Wachter, R. S. Treseder & M. K. Weber, Shell Development Co., *Corrosion* 3, 406-414 (1947) Aug.

The inhibiting effect of arsenic compounds on the corrosion of carbon steel by sulfuric acid is known. The present paper is concerned with inhibition of attack by sulfuric acid above 50% concentration, as used in petroleum processes. Experimental results are charted.

Action of Inhibited Hydrochloric Acid on Boiler Tubes. J. L. Wasco & F. N. Alquist, Dow Chemical Co., Paper, ASME Mtg., Chicago, June 16-19, 1947. Abst. *Power* 91, No. 8, 156 (1947) Aug.

Effect of inhibited hydrochloric acid solutions on boiler tubes of various specifications is presented. Tests were made at 150, 160, and 180° F., using three inhibitors and four concentrations of hydrochloric acid solution. Graphs show effect of acid concentration, temperature, and addition of boiler scale on the corrosion rates.

Cutting Oil Corrosion of Cemented Carbide Tool Tips. M. Jacobson. (PB 49077) (Watertown Arsenal Lab. Memo Rept. 336/3) Nov., 1945, 11 pp. M-\$1.00. P-\$1.00; *Bib. Sci. Ind. Rep* 4, No. 6, 485 (1947) Feb. 7.

An investigation was made to determine the cause and nature of corrosive action of cutting oils on cemented carbide tool tips used in Watertown Arsenal production shops. It was found that: (1) The presence of moisture in cutting oils other than those of the soluble oil type induces corrosive attack of the cobalt binder constituents of cemented carbide tool tips; (2) absence of corrosive action in the case of soluble cutting oils is attributed to the inherent inhibitive characteristics of water emulsions of oils of this type; and (3) of the lubricants subjected to the present tests, moisture-bearing sulfo-chlorinated cutting oil displayed the most pronounced attack at the cobalt matrix of the cemented carbides. Tables, including those in Appendix A, photomicrographs and graph are presented.

Use of Corrosion Inhibitors in Products Pipelines—A Survey of Practices. I. M. Parker, Plantation Pipe Line Co., Paper before API Transp. Div. 26th Ann. Mtg., Chicago Nov. 11, 1946, *Corrosion* 3, 157-168 (1947) Apr.

Of 18 companies reporting in a survey of 20 companies operating products pipelines, 12 use corrosion inhibitors in their lines, three are contemplating using an inhibitor, one dehydrates the products, one experiences no corrosion difficulties in any of its equipment, and one did not indicate its position. Mechanism of inhibitor action is reviewed briefly, with particular attention to the action of the chromate, nitrite and mercaptobenzothiazole inhibitors. It is pointed out that the major portion of the research on products pipeline inhibitors has been done by Phillips Petr. Co., The Atlantic Refg. Co. and Shell Oil Co. Phillips adopted the use of mercaptobenzothiazole for its lines, Atlantic developed the use of sodium chromate, while Shell's choice has been sodium nitrite. A copy of the questionnaire used in the survey and the tabulated answers, as well as data on the toxicity of sodium chromate and nitrite are included in the appendix.

INSPECTION

Application of Supersonics in Industrial Inspection. James W. Dice, *Engrs. D.* (Amer. Edition), 4, 352, 396 (1947) Aug.

Two basic testing techniques are in use in industry today. The first, or "through transmission" method employs two transducers, one to send the supersonic vibration into the test piece and the other to receive the transmitted vibration as it emerges from the other side of the piece. The second basic testing technique, the "reflection" method, is the one which has had wide acceptance in American industry. The instrument used is known as a Reflectoscope. The principle of operation of the Reflectoscope is that it sends supersonic vibrations through the material under test and measures the length of time it takes these vibrations to penetrate the material, reflects from the opposite side, or an internal defect, and returns to the sending point.—BLR.

METAL FAILURE

Estimation of Scaling Resistance. Howard S. Avery, *Alloy Casting Bull.* 9, 12 (1947) May.

Presents nomographs prepared by Battelle Memorial Institute for use in estimating the approximate corrosion resistance of iron-nickel-chromium alloys, to

oxidizing or reducing (flue gas) atmospheres at elevated temperatures.—BLR.

Effect of Artificial Aging on Tensile Properties and Resistance to Corrosion of 24S-T Aluminum Alloy—RP1788. H. L. Logan, H. Hessing & H. E. Francis, Nat. Bur. of Stds., *J. Res. of Nat. Bur. of Stds.* 38, No. 5, 465-489 (1947) May.

The effect of aging commercial 24S-T aluminum alloy sheet for various periods at 350, 375, 385 and 400° F., on its tensile properties and resistance to corrosion was determined. Aging for 3 hours at 385° F. produced an increase in yield strength of about 25% over initial value of 50,000 pounds psi, increase in tensile strength of 3% above initial 70,000 pounds psi, and a decrease to about 1/3 the initial elongation of 17-18%. Approximately the same values were obtained by aging the material for 20 hours at 350° F., 5 hours at 375° F., and 1½ hours at 400° F. Materials aged 3 to 10 hours at 385° F., and 6-12 hours at 375° F., were generally immune to stress corrosion cracking and were no more severely damaged in corrosion media, sodium-chloride + hydrogen peroxide solution or marine atmosphere, than commercially heat-treated material exposed without artificial aging. Corrosion test data as well as apparatus are fully presented.—INCO.

Constitution and Stress Corrosion of the Aluminum-Zinc-Magnesium Alloys. E. Schulz & G. Wassermann, *Halstead Exploiting Centre Translation* (BIOS Publication BIOS/Gp2/HEC3758), 14 pp. (Translation of a Metallgesellschaft Report dated Aug. 17, 1940.)

Authors discuss possibility of producing a high-strength aluminum-zinc-magnesium alloy with good stress corrosion resistance and in particular discuss the following three aluminum alloys: 8% zinc, 0.8% magnesium; 6% zinc, 1.4% magnesium; and 4% zinc, 3% magnesium. Unlike the Duraluminum-type alloys, these can be cooled slowly from the solution heat-treatment temperature, (thereby improving the stress corrosion resistance) without making much difference to the mechanical properties. Manganese increases the stress-corrosion resistance and the strength, but presence of 1% manganese reduces age-hardening power of slowly cooled alloys.—BNF.

German Theories and Accomplishments in the Field of Stress Corrosion Cracking. Charles A. Nagle, Hdqs. Air Nat. Command (Wright Field, Dayton, Ohio). Tech.

Rep. F-TR-1131-ND. 78 pp. (1947) June.

This report is amply illustrated with graphs, photographs, and charts. The period of scientific effort covered is from 1938 to 1944. It summarizes the work accomplished during the critical years in Germany which closely paralleled the efforts of metallurgists in the United States.—BLR.

Some Effects of Welding Heating Cycles on Heat- and Corrosion-Resisting Steels. H. Bull, *Metallurgia*, 36, 137-144 (1947) July.

Discusses the three main types of steels used, and some of the effects of the welding heat on material adjacent to the weld. The effects of the welding heat are considered with respect to the consequent changes in structure, corrosion resistance, mechanical properties, etc., and some account is given of the metallurgical steps taken to overcome them.—BLR.

Heavy-Metal Inserts (in Magnesium and Aluminum Alloys) and Corrosion. A. J. Ferko, Boeing Aircraft Co., *Light Metals* 10, No. 115, 418-421 (1947) Aug.

Short account of work on effect of inserts on the corrosion of magnesium casting alloys and on the use of the Alrok process for treating aluminum-alloy pressure die castings with cast-in inserts. Unlike anodising, the Alrok process (immersion treatment in a dichromate sodium carbonate solution) can be applied without having to mask the insert, while corrosion protection obtained is similar.—BNF.

Insulation of Dissimilar Metal Faying Surfaces. B. W. Floersch, Ryan Aeronautical Co., *Corros. & Matl. Prot.*, 4, No. 4, 16-18 (1947) July/Aug.

As a result of his investigations, the author makes recommendations for the protection of Dural surfaces in contact with cadmium-plated low-carbon steel and of magnesium alloy in contact with 18/8 and Alclad. Tests were carried out in salt spray. Organic materials considered.—BNF.

An attempt to Select a Suitable Specimen for the Study of Corrosion Cracking in 18-8 Steel. M. H. Springer, E. V. Succop, D. S. McKinney & M. A. Scheil, *Welding J.* 26, 530s-538s (1947) Sept.

Results of an extensive investigation of various types of test specimens, following a series of heat treatments, are discussed, tabulated, charted, and illustrated. It is shown that corrosion crack-

ing of austenitic stainless steels requires a rather critical combination of heat treatment, applied stress, and corroding environment. Other conclusions are drawn and a program for recommended future research is outlined.—BLR.

Stress Corrosion Cracking of High-Chromium Steel. (E. Zh. Z.) (In Russian), L. A. Glikman & V. A. Stepanov, *Boiler & Turbine Constr.* (USSR), 19-21, 1947, Feb.

Describes cases of the failure of bushings on the shafts of turbines. It is established by experiment that the failure of the above steel was caused by stress-corrosion cracking. A mechanism is proposed for the latter.—BLR.

Graphitization of Steels at Elevated Temperatures. Albert E. White, *Metal Prog.*, 52, 371-375 (1947) Sept.

A tendency for carbide to graphitize in steel pipe and fittings in high-pressure steam systems, discovered in 1943, has been combatted by specifying coarse-grained structure in the pipe—which prevents the steelmaker from deoxidizing the melt with aluminum, the greatest single promoter of instability of carbide—and by adding chromium to pipe, castings, and forged fittings for promoting stability of carbides.—BLR.

Reversion and Stress Corrosion of Aluminum-Zinc-Magnesium Alloys. G. Wassermann, *Halstead Exploiting Centre Translation* (BIOS Publication BIOS/Gp2/HECO3757), 16 pp. (Translation of a Metallgesellschaft Report dated Nov. 15, 1943.)

Author has shown that by ageing an aluminum alloy containing 4.3% zinc, 2.5% magnesium and 0.6% manganese at two temperatures, the last being higher than the first, it is possible to obtain high values for U.T.S. and proof stress in a short time. It was found that the stress-corrosion resistance was considerably improved by this treatment.—BNF.

Corrosion Studies for the Petroleum Refining Industry. Part I—The Economic Aspects of Corrosion. F. A. Rohrman, Kansas State College, *Petro. Refr.* 26, 513-18 (1947) June.

The economic aspects of corrosion and basic corrosion theory are discussed. Means of reducing corrosion by routine maintenance, inspection, and replacement has long been the conventional answer to corrosion difficulties, while newer effective methods such as the use of more resistant construction materials, water treatment, counter-electrolytic protection, and

others, have usually been reserved for the difficult cases. Chemical reactions leading to corrosion, including local galvanic action and the action of oxygen, which occur only under ideal conditions are considered in this section.

Electrolytic Oxidation of Aluminum-Magnesium-Zinc Alloy Hy-43. O. Lohrmann, Hdqs. Air Mat. Command (Wright Field, Dayton, Ohio). Translation No. F-TS-1858-RE. 19 pp. (1947) Aug.

An attempt was made to use the aluminum-magnesium-zinc alloy Hy-43 as aircraft material and it was found that by adding chromium, the material was suitable for that purpose. To increase its resistance against corrosion, Hy-43 is to be anodized. The tests are being continued, but the method is considered acceptable for giving Hy-43 the added protective corrosion proof layer.—BLR.

Investigation of Stress Corrosion Susceptibility of Homogeneous Alloys. I. Graf, Ministry of Supply, *R.A.E. Library Translation* No. 182, 29 pp. (1947) June. (Translation of ZWB Forschungsbericht (FB) No. 1954 of the Kaiser-Wilhelm Institut für Metallforschung, April, 1944.)

Account of work on stress corrosion susceptibility of silver-gold and gold-copper alloys in 2% ferric chloride solution. The susceptibility depends on the gold content in both cases, maximum susceptibility occurring at approximately 50% gold. The author discusses the electrochemical part of the process at great length and comes to the conclusion that the susceptibility of single-phase alloys is governed by the electrochemical potential difference between the alloying components and by the type of corroding agent. Question of why the corrosion is concentrated along some particular path is not raised.—BNF.

PIPELINE CORROSION

Plastic Insulation Provides Protection Against Stray-Current Corrosion in Wells and Piping Systems. J. A. Clay, Jr., Service Eng., Inc., *Oil & Gas J.*, 46, No. 12, 245-46+ (1947) July.

Insulation against stray currents in wells obtained through the use of laminated plastic materials is described. The materials are made either in the form of common pipe fittings or as accessories for existing fittings. For pipe lines operating at pressure of 1000 psi. or less, plastic pipe nipples or bushings are recommended. For equipment operating at pres-

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tures exceeding 1000 psi. or of such large size that nipples cannot be used, an insulated flange must be used. Installation and selection of the plastics is discussed.

Corrosion Control for Gas Mains—The Plant Notebook. A. H. Tell, *Chem. Eng.*, 54, No. 3, 123 (1947) Mar.

A method of alleviating corrosion in systems handling corrosive gases is to install internal spray nozzles in the gas mains. Although efficiency is low, use of sufficient nozzles will permit satisfactory results. To remove the liquid mist in the gas a knock-out drum or its equivalent is required—design dependent on nature of corrosive agent and system involved. Caustic soda, solution, boiler blow-down or other similar spray materials will provide satisfactory results. A typical flow diagram is sketched.—INCO.

REFINERY CORROSION

Corrosion of Refinery Equipment—A Review. E. F. Kerns, *Corrosion*, 3, 291-294 (1947) June; *Abst. Oil & Gas J.*, 45, No. 23, 96 (1946) Oct. 12.

Discusses selection of crude; hydrogen sulfide and mercaptan sulfur; total chloride content (total salt); total sulfur; neutralization.

Corrosion Studies for the Petroleum Refining Industry. Part II. Factors Affecting Corrosion. F. A. Rohrman, Colorado Univ., *Petro. Refr.*, 26, 793-798 (1947) July.

Following factors affecting corrosion are discussed: (1) Metal (a) electromotive position, (b) purity, (c) nature of impurities, (d) physical state, (e) oxide or surface behavior; (2) Corroding medium (a) salt solubility, (b) nature of cation, (c) concentration of cation, (d) electrical conductivity, (e) diffusivity (temperature and viscosity), (f) nature of anion, (g) nature of corrosion products; (3) External influences (a) oxygen concentration (b) light, (c) colloids, (d) bacteria, (e) cathodic metals and (f) stray currents.

Corrosion Studies for the Petroleum Refining Industry. Part III. Corrosion Tests. F. A. Rohrman, Colorado Univ., *Petro. Refr.* 26, 651-655 (1947) Aug.

Six types of accelerated corrosion tests: electromotive, total immersion, partial immersion, salt and acid spray, wet and dry, and color tests, are discussed. Corrosion prevention by alloying, removal of strains, polishing, producing insoluble oxide coatings, producing insoluble phos-

phate coatings, electroplating, covering with metals other than by electroplating, covering with non-metallic materials, making cathodic with external electromotive force, and treatment with corroding media are briefly described.

Corrosion Tests in Distillation Equipment. W. Z. Friend & J. F. Mason, Jr., International Nickel Co., *Petro. Eng.*, 18, No. 8, 192 (1947) May.

Results obtained from a number of plant corrosion tests in atmospheric crude distillation and in the separation, fractionation and stabilization of primary products from thermal cracking are presented. The spool-type specimen holder used in the tests is described and illustrated. Testing techniques are described. Corrosion rates are given in inch penetration per year; the maximum depth of pitting is also reported. Corrosion is discussed with reference to both atmospheric crude distillation and the distillation of products from thermal cracking. In the former, Ni-resist austenitic cast-iron alloys (14% nickel and 6% copper, or 20% nickel) are claimed to be more resistant than cast iron under dilute acid conditions. In the latter, 4-6% chromium steels are adequate. Tables are given showing the compositions of metals and alloys used and the results of the tests. The best alloy for each situation is suggested, as follows: (1) the top of crude topping towers (Monel), (2) straight run gasoline from crude topping towers, and (3) water layer in reflux water separators (Admiralty brass, copper-nickel alloy, or Monel, depending on the acidity), (4) the bottom of crude topping towers (austenitic stainless steels), (5) vapor separator thermal cracking of gas oil, and (6) fractionation of pressure distillate from thermal cracking of gas oil (austenitic stainless steels or 4-6% chromium steels), (7) fractionation of cracked gasoline (Admiralty brass better than alloys of higher copper content under high temperature conditions), and (8) the bottom of stabilized gasoline re-run tower (Monel).

Modified Type 405 Stainless Iron—A Satisfactory Lining for Petroleum Refinery Vessels. M. A. Scheil, A. O. Smith Corp., *Metal Prog.*, 52, No. 1, 91-101 (1947) July.

Experience of A. O. Smith Corp. with Type 405 stainless in petroleum refinery equipment is reported with a discussion of why it is preferred to Type 410 and considerable data from tests in service comparing Types 304, 316, 347, 405, 410, 430,

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and 501. Six (rare) cases of brittle failure of Type 405 are analyzed in detail. Experience indicates that Type 405 or 410 with 0.08% carbon should be modified from 11.5-13.5% chromium to 11.0-13.0% chromium and if carbon is specified as 0.06%, chromium should be decreased to 11.0-12.5% range. Evidence of age hardening in both alloys is attributed in Type 405 to chromium content over 13%, and in Type 410 to a prior cold worked structure in alloy strip which accelerated age hardening. Graphs and tables give: results of Huey corrosion tests of Types 405, 410 + molybdenum and + columbium, and 430; corrosion and pitting of various types in service after 6250 hrs.; hardness of Types 430, 410, and 405 after water quenching or air cooling from various temperatures; hardness of Type 410 and 405, furnace cooled from various temperatures; hardness and Charpy keyhole notched-bar tests on quenched and drawn Type 405; effect of aluminum on hardenability of Type 405; effect of 0.20% aluminum on microstructure of 11-13% chromium-iron; hardness of Types 430, 410, and 405 after long stay at elevated temperatures; mechanical properties of straight chromium alloys after 1050 hrs. at 800° F.; tensile test results on heat treated Type 405 bars; results of exposure of various alloys at 840-890° F. in ammonia converter.—INCO.

SURFACE PREPARATION

Shot Peening Increases Durability of Metal Parts. R. L. Mattson & J. O. Almen, General Motors Corp., Report for the National Defense Research Committee. *Compressed Air Mag.*, 52, No. 1, 134 pp.; *J. Franklin Inst.* 243, No. 4, 344 (1947) Apr.

Shot peening will greatly increase the service life of engine cooling fans, exhaust-valve rocker arms, and many other parts of steel machinery, according to report on experiments conducted over a 2-year period. Primary interest was in fatigue durability, but other properties such as static strength, impact resistance, hardness, friction, corrosion resistance, surface roughness, and surface failures also were tested. Shot peening lengthened the service life of torsion bar springs by from 700 to 900 percent and trebled the durability of engine cooling fans. Shot-peened exhaust valve rocker arms were found to stand up several times as long as polished ones, and the peening of undersized rocker arms made them equal in this respect to unpeened polished rocker arms of standard size. Peening also imparted greater service

life to some steel gears, as well as to specimens of aluminum-alloy sand castings, cold-drawn nickel and Monel, and soft Inconel.—INCO.

Influence of Different Additions in the Phosphating of Metals—Part I. Copper Compounds. I. I. Khain, *Zhurnal Prikladnoi Khimii*, 18, No. 4-5, 264-269 (1945).

Experimental study of the influence of copper additions to phosphating baths upon the acidity of the bath, the rate of coating formation, the color, the structural makeup, and the anti-corrosive properties of the phosphate deposit. Valence state, concentration of copper and type of copper compounds as related to activating effect upon phosphating process are discussed. A small addition of copper oxide to a mixture of zinc and phosphoric makes it possible to treat chromium-nickel-molybdenum steel which can be phosphated only with difficulty, if at all, in an ordinary solution. Tables give data on the duration of the phosphating process and results of tests for the rust-proofing properties of the coatings obtained in the presence of copper. 14 refs., mostly patents.—INCO.

TESTING

Copper-Strip Corrosion Tests. J. A. Bolt, Standard Oil Co., of Indiana, *Oil & Gas J.*, 46, No. 14, 99-100 (1947) Aug.; *Petro. Refr.* 26, 660-662 (1947) Aug.

Work is progressing on correlating the degree of corrosiveness of various light oil products with resulting colors of exposed copper-strip. Current corrosion tests are reviewed and the nature and cause of corrosion is discussed briefly. The work of S. O. Co.'s (Ind.) research staff is directed toward (1) finding a corrosive sulfur compound which can be added in incremental amounts to an originally non-corrosive stock or solvent such as n-heptane or cetane and (2) establishing a procedure to prepare satisfactory reference strips. It is planned that the corrosion number of the strip, or degree of corrosion, will be a mathematical function of the amount of corrosive sulfur present.

Performance Testing of Paints. H. Hollis, *Paint Technol.*, 12, 177-179; discussion, p. 179-181 (1947) May.

Discusses the above with particular reference to outdoor exposure.—BLR.

Corrosion Testing Facilities Expanded at Kure Beach. R. K. Lotz, *Steel*, 121, No. 2, 88-90+ (1947) July; *Motorship*, 32, No. 8, 24-28 (1947) Aug.



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It need not be! Producers in many fields have found in Transite a pipe that gives years of dependable service . . . eliminates costly pipe replacements. They know that because it is made of asbestos and cement, Transite is remarkably resistant to the corrosive action of salt water in the inside, corrosive soil on the outside.

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Facilities and current tests at the seawater corrosion testing station at Kure Beach, N. C. jointly maintained by International Nickel Co. and Dow Chemical Co. are described. About 2000 test specimens of all types of materials such as rope, steel, plastics, wood are submerged presently in sea water tanks. Tests are also conducted in streams of water. Results of 4 years exposure tests of specimens of Monel, nickel and Inconel in the atmosphere are tabulated. Results of tests on other steel specimens especially nickel steels are discussed.

Primary Etching of Welds. (In Swedish.) Erik Magnusson, *Jerkontorets Annaler*, 131, No. 6, 212-224 (1947).

Gives recommendations for reagents and procedures, and also for preliminary quenching and tempering to produce a finer microstructure. The mechanism of etching is discussed. Illustrated by some excellent photomicrographs.—BLR.

Study of the Chemical Surface Condition of Aluminum by Measuring the Potential of Dissolution. (In French.) P. Morize, P. Lacombe & G. Chaudron, Paper before Comm. Tech. des Etats et Propriétés de Surface des Métaux, Conf., Paris, Oct., 1946. *Journées des Etats de Surface*, (publ. by l'Office Professionnel Général de la Transformation des Métaux), 242-246 (1946).

The measurement of dissolution potential is a sensitive method for defining quantitatively the chemical surface condition of a metal. By this means, the growth of extremely thin oxide films upon simple contact with air at ordinary temperatures was brought out. It is concluded that only electrolytic polishing by Jacquet's method brings about aluminum surfaces free from oxide layers. Electrolytic polishing of corrosion specimens to be used in laboratory accelerated tests is recommended, since it diminishes dispersion of results making it possible to obtain completely reproducible surface conditions. In such tests, surface state should be defined chemically, not microgeometrically (e.g. by sanding, or polishing with abrasives). Suitable choice of electrolytic polishing baths and perfect control of conditions under which the polishing takes place are essential. It is noted that even when using Jacquet's bath, if too high temperatures are employed, oxide layers are formed. 5 refs.—INCO.

Rating Exposure Test Panels of Decorative Electro-Deposited Cathodic Coating. W. A. Wesley, *ASTM Preprint No. 38*, 12 pp. (1947).

A system for rating the results of outdoor atmospheric exposure tests of chromium-plated finishes with a nickel or nickel-copper undercoat should be based solely on the appearance of the test panels. Appearance is difficult to define and there is a great need of objective standards to lessen dependence upon the experience and cooperation of inspectors. A set of graphical reference standards was designed somewhat similar to that developed by the paint committee for rust resistance. A system of numerical ratings to go with these is recommended which is similar to that employed in the recent cooperative exposure tests of the national Bureau of Standards, the American Electroplaters' Society and the ASTM. The new scale is set at a higher quality level because the behavior of coatings during the later stages of corrosion is considered of little practical interest. The paper is concluded with a discussion of the interpretation of inspection data. 9 refs.—INCO.

Atmospheric Weathering Tests on Anodized Aluminum Reflectors. W. E. Harper, C. A. Morton & P. Smith, *Trans. Illuminating Engr. Soc. (USA)* 175-201; *Light Metals Res. (England)*, 8, No. 10, 266-267 (1947) May 16.

Specular and matt anodized reflectors of different grades of aluminum were exposed for two three-month periods, aluminum will only function satisfactorily in certain types of atmosphere. At present, it may be regarded as satisfactory in dry atmospheres, i.e., locations where the surface is never wetted; thus it should function in fittings designed for use in many industries of the lighter kind, in school and office lighting, in shop window and store lighting, and in enclosed units used out-of-doors, such as floodlights. On grade B aluminium specular reflectors, an anodic film thickness of 0.0003-inch is recommended as offering the optimum combination of reflectivity and protection. If super-purity metal is used, the film thickness may be increased to 0.0005-inch without markedly affecting the value of the specular reflectivity, while giving greater tolerance in treatment and increased resistance against pitting. Experience during the test suggests that dirt tends to adhere to anodized surfaces more tenaciously than to surfaces of vitreous enamel or glass.—ALL.

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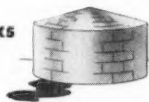
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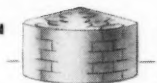
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Chromate Corrosion Control for Engine-Jacket Water. Marc Darrin, Mutual Chem. Co. of America, *Corros. & Metall. Prot.* 4, No. 3, 6 (1947) May-June.

Directions are given for use of chromate (or bichromate) in various cooling systems for internal combustion engines. These include data for chloride-containing waters, from which optimum concentrations of chromate may be estimated for tower coolers and similar heat-exchange equipment which are commonly encountered in diesel power plants. In general, it is best to start an open system with a fairly high concentration of chromate, 500 to 1000 ppm., after the protective film has formed. For these systems it is a waste of time and material to start with concentrations that are too low, as the consumption of chromate may be exceedingly rapid under such conditions. For commonly encountered enclosed systems, consumption of chromate is almost negligible; and for convenience, it is customary to use a concentration of about 1000 ppm. in order to eliminate frequent inspection. In small systems, sodium chromate is employed because of its convenience; while it is customary in large systems to use sodium bichromate plus caustic because of lower cost. For ready-prepared mixtures for automobile radiators, sodium bichromate is unsuited because it tends to cake in a humid atmosphere; for this reason sodium chromate or potassium bichromate are preferable.—CEC.

On the Action of Water and Atmospheric Air on Copper. A. Quartaroli, *Korrosion u. Metallschutz*, 18, No. 11/12, 368-370 (1942); *J. Inst. of Metals & Metall. Abs.*, 14, 103 (1947) March.

In the presence of air, the solubility of copper in distilled water is comparable to that of cuprous oxide in water.—INCO.

Electrolytic Resistance as a Means of Evaluating the Protective Merit of Under-Water Organic Coatings on Metals. R. C. Bacon, J. J. Smith & F. M. Rugg, Bakelite Corp. ACS 111th Mtg. Atlantic City, April 14-18, 1947; Abstr. of papers: 6-7-N

An electrolytic resistance technique for evaluating underwater organic coatings, generally in 1/5 the time required for the usual exposure test. It has proved reliable in more than 300 test systems. In the course of this work, a wide variety of the factors which affect the protection offered by submerged coatings on mild steel substrate has been considered. The effects on protective performance due 1) to dif-

ferences in the pigment, the pigment content, and the organic binder, 2) to the presence of a "wash primer" applied to the steel substrate prior to the application of the primer coating, and 3) to variations in sodium chloride and oxygen concentrations in the environment have readily been revealed by log resistance time curves. With coatings offering good protection, alternate increases and decreases in the high resistance region are frequently observed throughout the course of the test immersion period. The phenomenon is believed to be related to the formation of corrosion product barriers at or near the metal surface.

Details of Corrosion Testing Methods.

L. W. Haase, *Korrosion u. Metallschutz*, 19, No. 8, 224-229 (1943); *J. Inst. of Metals & Metall. Abs.*, 14, 104 (1947) March.

Details and illustrations are given of ten methods of carrying out corrosion tests by which all known forms of corrosion can be reproduced. The factors influencing the accuracy of the tests are discussed, and the importance of proper interpretation of the results is emphasized.—INCO.

Corrosion Resistance of Spot-Welded Aluminum Assemblies (In French). Nicolas Beliaeff, *Revue de l'Aluminium*, 24, 3-9 (1947) Jan.

A series of corrosion tests (alternate immersion in salt atmosphere at room temperature and at 40° C. and long-time tests in sea water) has been performed on spot-welded aluminum alloys.—BLR.

UNDERGROUND CORROSION

Oil Pumped Under Steel Tank to Prevent Corrosion. Lorraine R. Voight, *Engr. News Rec.*, 138, 96, 1030 (1947) June 26.

In an effort to prevent possible corrosion on the underside of the bottom plate of steel water tanks, officials of the East Bay Municipal Utility District in California have adopted a system of pumping low grade oil under the tank. Although small samples cut from the bottom plates have given no indication of trouble, reports of tank failures elsewhere due to such corrosion have prompted district officials to adopt such a system. To provide means of access for the oil, a 3/4-in. welded tap is made at the center of the tank bottom. Then some 40 to 75 gal. of low grade oil is pumped through the tap into the sand cushion under the tank bottom by means of a hand pump. Enough oil is forced in until the tank bottoms raise

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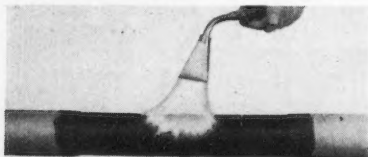
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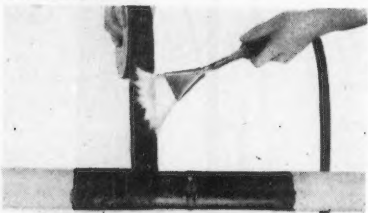
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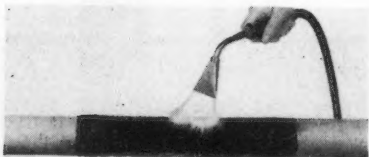
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STEP 2 Start wrapping TAPECOAT where kraft paper has been removed. Flash flame of torch lightly on TAPECOAT to bleed its coating. Secure double thickness of TAPECOAT by overlapping slightly more than half the width of the tape.



STEP 3—Finish wrapping TAPECOAT. When wrapping is completed, flash the torch flame over entire TAPECOATED section to bleed coating to a shiny surface.

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slightly in the center. The addition of a load of water in the tank is expected to force the oil from a location relatively near the center of the tank out to the side of the tank, thus coating the entire bottom with a film of oil. A regular program of such a protective measure is contemplated.—INCO.

Experimental and Theoretical Investigations of Cavitation in Water. J. Ackeret, Eidgenossischen Technischen Hochschule in Zurich (Berlin) 1930. *NACA Tech. Mem.* No. 1078, 61 pp. (1945) May.

The cavitation in nozzles on airfoils of various shape and on a sphere are experimentally investigated. The limits of cavitation and the extension of the zone of the bubbles in different stages of cavitation are photographically established. The pressure in the bubble area is constant and very low, jumping to high values at the end of the area. The analogy with the gas compression shock is adduced and discussed. The collapse of the bubbles under compression shock produces very high pressures internally, which, according to more recent conceptions, are contributory factors to corrosion. The pressure required for purely mechanical corrosion is also discussed. 17 refs.—INCO.

Interim Report on External Deposits and Corrosion in Boiler Plant. *Boiler Availability Committee Bull.* M. C. 153, 26 pp. (1947).

Nature of external deposits (high-temperature deposits, low-temperature deposits and corrosion); mechanism of deposit formation (results of analytical and physical determinations; results of combustion experiments; significance of sulphur oxides; effect of fine dusts and "smokes"); factors affecting deposit formation (design of plant; operation and maintenance; fuel). (Note: These reports are published mainly for the benefit of power station engineers in this country; industrial companies who require copies for retention should send requests to the makers of their water-tube boilers.)—BNF.

The Corrosion of Water Heaters. N. Booth, P. C. Davidge, G. H. Fuidge & B. Pleasance, *Gas Research Board Publ.* 27; *Gas J.* 248, 1047, 1090-1094 (1946); *Ibid.* 249, 95-98 (1947); *Chem. Abs.*, 41, No. 9, 2686 (1947) May 10.

Two standard models of instantaneous, sink water heaters were subjected to an accelerated life test. In both cases the

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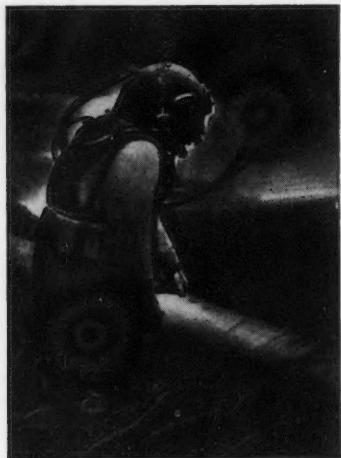
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heater and fins were constructed of tinned copper. It was found that then the sulfur content of manufactured gas used as fuel was reduced from 17 to 3 grains per 100 cu. ft., there was an almost corresponding reduction in the amount of corrosion on the gas side. Gas containing 0.1 grain of sulfur per 100 cu. ft. gave considerably more corrosion than that containing 3 grains. The min. sulfur content is probably in the neighborhood of 3 grains. Only very small amounts of nitrogen products with the gas containing 0.1 grain of sulfur in which more nitrate than sulfate was found in the deposits. Heaters in which the metal coating of the copper was richer in lead and about 20 times as thick as in the other type showed rather less corrosion. In all cases the rate of formation of corrosion deposits increased with time.—INCO.

WATER CORROSION

Corrosion in Condensate Return Lines Studied (Concluded). John F. Collins, Jr., *Heat, Piping & Air Cond.*, 19, 108-110 (1947) Sept.

Secondary Treasurer of National District Heating Association completes report of 38th annual meeting of NDHA.—BLR.

Algae, Scale and Corrosion Control. G. F. Lebrecht, Anheuser Busch, Inc., *la Refrig.*, 112, No. 1, 35-9.

A series of tests for the control of corrosion in ammonia condensers were performed using the following chemicals as inhibitors: lime, caustic soda, sodium silicate, sodium silicate combined with soda ash, caustic soda and phosphate, and phosphate alone. The specimens were pieces of mild steel about 1/2-inch square and 1/4-inch thick, highly polished on two opposite sides. It was impossible to control pH values to the extent that any corrosion protection could be obtained without forming excessive scale. The best treatment was obtained using a form of sodium metaphosphate which shows an average weight loss of 4 mg. per 500 sq. cm. Results tabulated.

Corrosion: M. G. Fontana, Ohio State Univ., *Ind. & Eng. Chem.*, 39, No. 1, 89A-90A (1947) Jan.

The extent and importance of corrosion problems are briefly outlined, with emphasis on reasons chemists and chemical engineers have a vital interest in it. These are: trend toward higher temperature

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PIPE Steel and Concrete	Corrosion of interior of pipe caused by chemicals, food products, sewage, sour crude; also by electrolytic action. Contamination of contained product by iron or calcium pick-up. Exterior of pipe subject to chemical and electrolytic corrosion.	For maximum resistance to severe conditions, AMERCOAT Plastic Lined Pipe is recommended. For sewage, petroleum, food products, and milder chemicals, AMERCOAT No. 23, 44 or 55 are used. Exterior of piping subject to corrosive chemicals, fumes, and soil corrosion, AMERCOAT No. 33 provides outstanding protection.
TANKS AND TANK CARS	Corrosion of interior caused by acids, salts, alkalies, petroleum products, and organic chemicals. Contamination of contained product by contact with iron. Vapor space corrosion. Varying temperatures. Corrosion of exterior caused by weathering, chemical fumes and spillage of contents of tank.	Interior—AMERCOAT No. 23 is a general purpose lining material for concrete and metal tanks for both chemicals and food products. AMERCOAT No. 44 is designed for concentrated acids and salts; AMERCOAT No. 31 and 55 for concentrated alkalies and salts at elevated temperatures. Write for recommendation on your specific problem. Exterior—AMERCOAT No. 33 is recommended for maximum resistance to weathering, chemical fumes, and spillage.
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PROCESSING EQUIPMENT Clarifiers, Filters, Blowers, Ducts, Pumps, Conveyors, Scrubbers, Etc.	Corrosion due to acids, salts and alkalies; spillage, fumes and moisture condensation.	AMERCOAT No. 33 recommended for most exterior surfaces of process equipment at temperatures up to 150° F. AMERCOAT No. 61 recommended for stacks and other hot surfaces at temperatures to 600° F. Write for recommendations for lining process equipment.

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and pressures, desire to reduce maintenance costs, need for pure products, loss of valuable chemicals, and safety. Improvement of sodium hydroxide by avoiding color pick-up from cast iron pots, importance of nickel and nickel alloy equipment in production of rayon-grade caustic and an example of plant shutdown because of sudden and rapid corrosion of stainless steel equipment (involving centrifugals) are mentioned.—INCO.

Corrosion and Protection of Iron in the Storage and Transportation of Fuels. *Technique Moderne*, 185-6 (1946) Aug. 1 & 15; abstr. *Chal. Ind. No.* 259:8D (1947) Feb.

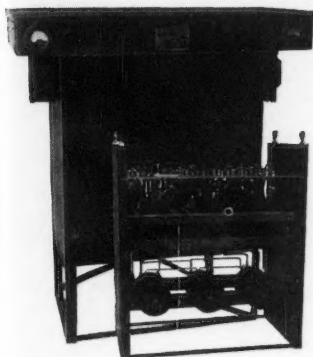
Corrosion protection in underground tanks has been found effective by the application of a thin layer of cement hardened by a magnesium fluorosilicide solution as developed by I. G. Farben. The upper portion of the tank, however, should be coated with appropriate materials. During test procedures the fuel was dehydrated with soda and the tank purged of all moisture. No definite conclusions have been reached.

Resistance of Aluminum Alloys to Fresh Waters. D. W. Sawyer & R. H. Brown, Aluminum Co. of America, *Corrosion*, 3, 443-457 (1947) Sept.

Authors present a comprehensive study of the attack on aluminum base alloys by: (1) waters containing heavy metals such as copper, nickel and lead, (2) neutral or nearly neutral waters, (3) alkaline waters, (4) acid waters. Local pitting of various aluminum alloys by water containing heavy metals is attributed to electrochemical corrosion. Alcladding has proved to be the remedy. Neutral waters have little effect upon aluminum base alloys which are safe for use with water having a pH range of 8.5 to 9 or below. Aluminum alloys are affected by very acid waters such as mine waters containing large amounts of ferric ion, but they have been used with satisfactory results. They have proved resistant to sulfide and sulfite bearing waters such as those found in the brines from oil wells. Some tap waters have been found to be definitely corrosive to aluminum alloys, as are practically all re-circulated waters because they hold in solution substantial amounts of heavy metals and concentrated salts. It is sometimes feasible to use a corrosion inhibitor such as sodium chromate. Where this is uneconomical or undesirable, cathodic protection by means of zinc strips or plates may be used.—ALL.

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Failures of Domestic Hot-Water Storage Tanks; (2) Corrosion of Galvanized Hot-Water Storage Tanks. (1) C. P. Hoover; (2) J. B. Bialosky, *J. Amer. Water Works Assoc.*, **38**, 1005-1019 (1946) Sept.; *Corrosion*, **3**, 185-191, 192-197; discussion 197-200 (1947) Apr.

(1) Discusses factors contributing to cases of rapid failure and outlines various preventive measures, indicating results obtained in service tests. (2) Classifies the factors promoting corrosion as being "internal" (i.e., arising in the tank itself) or "external" (i.e., arising from the water supply or the heating system as a whole). O. Rice, in discussion on both papers, discusses further factors (pH, presence of dissolved copper, Calgon treatment).—BNF.

Cost of Corrosion to the Water Industry. Harry E. Jordan, *Corrosion*, **3**, 367-373 (1947) Aug.; *J. Amer. Water Works Assoc.*, **39**, 773-778 (1947) Aug.

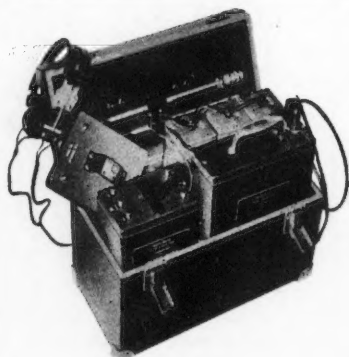
Discusses cost according to size of industry, restoring capacity, cost of relining, and methods of reducing corrosivity. Deals primarily in cast iron pipe. Non-ferrous metals omitted.

Development in the Application of Sodium Hexametaphosphate for Corrosion Control. J. P. Klebter, Hall Labs., W. Va. *Eng. Expt. Sta., Tech. Bull.*, No. 23, 47-51 (1943).

Sodium hexametaphosphate originally introduced to prevent calcium carbonate scale deposition is now also used for corrosion control. Laboratory tests on steel wool and black iron pipe show corrosion reduction is obtained because of formation of a protective film of absorbed metaphosphate on surfaces of metal. Once this film is formed, only small concentrations of metaphosphate are required to maintain it. Best results were obtained with pH values above 5.

Zinc-Iron Couple in Water at Elevated Temperature. George D. Lain, *Corros. & Metall. Prot.*, **4**, 12-15 (1947) July-Aug.

Discusses the possibility of a reversal in potential of the zinc-iron couple in natural waters at elevated temperatures with emphasis on the behavior of hot-dipped galvanized steel pipe in a natural water with a total hardness of less than 60 ppm expressed as calcium carbonate, and carrying dissolved oxygen and car-



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bon dioxide close to the point of saturation.—BLR.

Experience with Internal-Boiler-Surface Corrosion in 1450-Pound Open-Pass Boilers at West End Station of the Cincinnati Gas and Electric Company. E. H. Mitsch and B. J. Yeager, *Trans. ASME*, 69, 487-491; discussion, 500-503 (1947) July.

A pit type of corrosion occurred in Apr., 1940 after three years of operation without difficulty. In Feb., 1941, the first failure by corrosion at the rolled joints of tubes occurred. This type of corrosion stopped being active about the beginning of 1942 and had not recurred up to June, 1946. Conditions of operation, boiler-water concentrations, and other factors are described and compared in order to determine the causes of corrosion or to determine the factors responsible for arresting it.—BLR.

Silica Deposits in Steam Turbines from Softening of Makeup Through Natural Zeolite. F. R. Owens, Cyrus Wm. Rice & Co., Paper before 7th Ann. Water Conf., *Combustion*, 19, No. 1, 37-39 (1947) July.

Data from a number of plants show an

increase in silica content by the water in passing through a softener employing green sand. Seasonal increase of the silica content is also noted. Curves are included showing turbine performance prior to and after bypassing the green sand softeners. Blasting with fly ash proved much more effective in removing turbine deposits than washing, even over prolonged washing periods. The theory that the presence of silica in steam is selective, is confirmed.—INCO.

Investigation into Corrosion Problems at the Fulham Power Station. Metropolitan Borough of Fulham, Electricity Dept. Brochure, 50 pp. (1946) Nov.

Following on an explosion in a boiler unit at Fulham Power Station which disclosed large-scale corrosion, an investigation was carried out which is here reported. It is concluded that the prime cause of the trouble was incorrect water treatment during the early life of the plant. Methods and equipment have been revised to avoid corrosion troubles and to provide facilities for rapidly checking and controlling bad conditions as and when they arise.—BNF.

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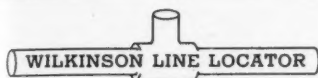
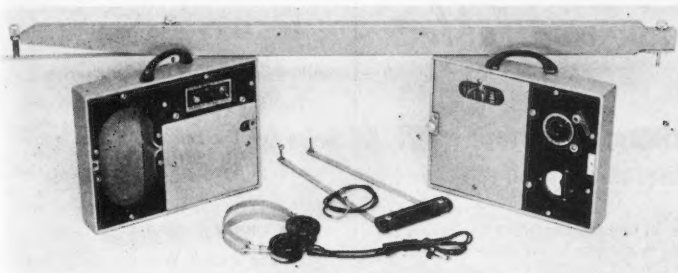


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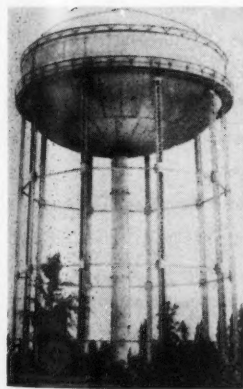
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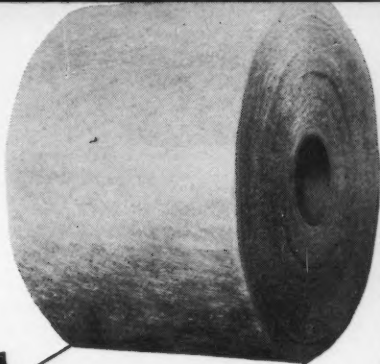


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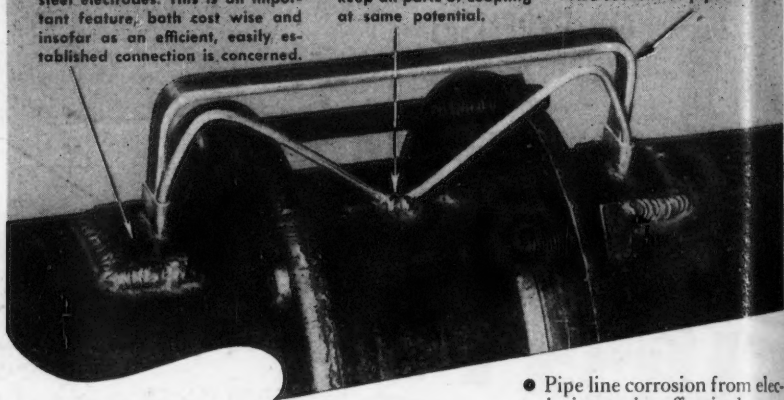
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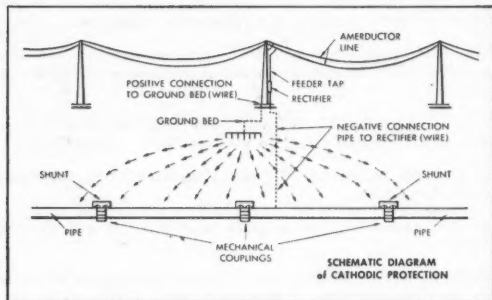
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